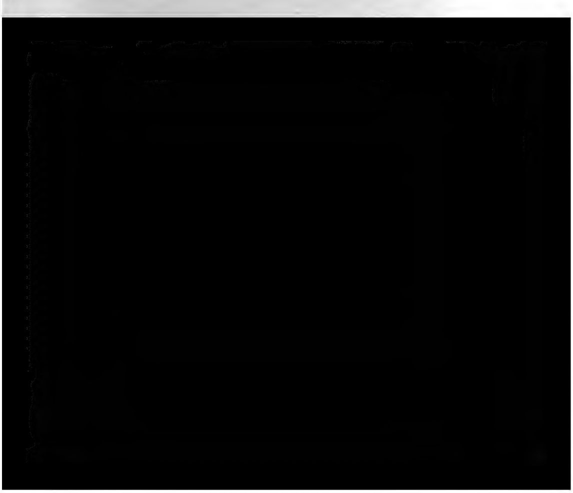

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RIDER'S

LITTLE ENGINEER

A POCKET-BOOK

OF ENGINEERING AND OTHER DATA RELATIVE TO MANY SUBJECTS.

INSTANT ANSWERS

FOR ENGINEERS, CONTRACTORS OR OTHERS IN CHARGE OF OR HAVING TO DO WITH THE DESIGNING, CONSTRUCTION, OPERATION OR SUPERVISION OF

PUBLIC OR QUASI PUBLIC WORKS AND STRUCTURES OR DEPARTMENTS.

BY

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GRADUATE OF RENSSELAER POLYTECHNIC INST., 1889.

SPECIAL PH. D. COURSE, LAFAYETTE, 1890.

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HOME OFFICE AND LABORATORY,

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For Price, Etc., See Part 2, Page 47.

PREFACE.

The Little Engineer has no apology to make.

It is simply a compilation, taken for the most part from the author's private note books.

It is intended for the use of up to-date officials and others, who can, if occasion requires, take the place of any subordinate, run the boiler, take the pump apart, rig the derrick, mix the mortar, caulk the joint.

Such men are, to a greater or less degree, familiar with the scientific principles involved in their work, and the Little Engineer does not attempt to go into detail in this direction. In fact it relates little they did not once know, but may for the moment have forgotten, or could find out if given time enough.

It simply attempts to aid in giving the quick and positive decisions that the very nature of their vocation demands.

It gives this aid in tabulated and connected form and otherwise in a manner that the author in working side by side with them has found convenient and practical in the field, office, plant, on the witness stand and elsewhere.

Many of the tables are and much of the data is original and verified by costly experiments. For other matter contained, not common property, but the result of tedious labor of others, due credit is given.

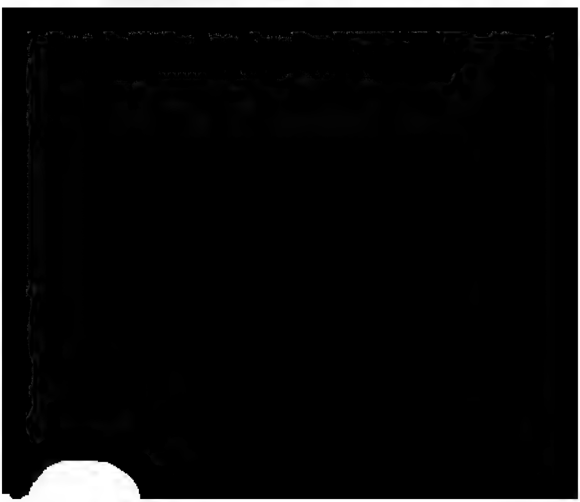
In order that the book can be conveniently carried in an ordinary pocket, the "type page" is 3" in width; this has prevented uniformity in style and size of type and necessitated much "setting up" and subsequent reduction of tabular and other matter.

Certain problems of importance, such as the flow of rivers, etc., cannot be properly answered by tabulated information. In such cases, reliable formulæ, examples, etc., are given.

"Rust" will get on in spots—they need touching up. The machine may stop on "dead centre"—it needs a push. For these reasons much elementary data is contained that will at least assist, if it is not found sufficient.

JOSEPH B. RIDER.

South Norwalk, Conn.
June, 1901.



ARITHMETICAL AND ALGEBRAICAL SIGNS.

$=$ The sign of equality, and signifies, is equal to, or equals, as 4 and $6 = 10$.

$+$ The sign of addition, and signifies, plus or and, as $4 + 6 = 10$.

$-$ The sign of subtraction, and signifies, minus or less, as $10 - 4 = 6$.

$\times$ The sign of multiplication, and signifies, multiplied by, as $10 \times 4 = 40$.

$\div$ The sign of division, and signifies, divided by, as $40 \div 4 = 10$; or written $\frac{40}{4} = 10$, and read 40 divided by 4 equals 10.

$: \; :: \; :$ The sign of proportion; $:$ signifies, is to, or to; $::$ signifies so is. Thus $4 : 6 :: 8 : 12$ signifies that 4 is 6 so is 8 to 12.

$\sqrt{}$ The sign of the square root (termed the radical sign), as $\sqrt{16} = 4$.

$\sqrt[3]{}$ The sign of the cube root, as $\sqrt[3]{64} = 4$ reads the cube root of 64 equals 4. Likewise the 4th, 5th or any other root can be expressed by placing the number corresponding as the figure 3 is above placed.

5^2 signifies that 5 is to be squared, as $5^2 = 25$. The small figure 2 is termed the index or exponent.

5^3 signifies that 5 is to be cubed, as $5^3 = 125$, and reads 5 cubed equals 125. Likewise any other power of a number can be indicated by placing the number corresponding as the small figure 2 or 3 is above placed.

$\overline{}$ A vinculum placed over two or more figures, thus $\overline{6 + 2}$ signifies that they are to be taken as one quality. Thus, $\overline{6 + 2} \times 4 = 32$ signifies that 6 plus 2 multiplied by 4 equals 32, and $\sqrt{5^2 - 3^2} = 4$ signifies that 5 squared, minus 3 squared, and the square root of the remainder equals 4.

$\frac{(\overline{24 \times 6} + \overline{12 \times 3}) \times 4}{12} = 60$ signifies that 24 multiplied by 6, and 12 multiplied by 3, added together, multiplied by 4 and divided by 12 equals 60.

[ ] or ( ) Brackets or Parenthesis. $12 - [3 + (4 \times 2)] = 1$, signifies that the product of 4 multiplied by 2, added *to 3, and the total taken* from 12 leaves 1.

∴ is used to signify the word therefore.

∵ is used to signify the word because, or since.

$<$ is used to signify the words less than, and is
lled the sign of inequality. It signifies that the
ality placed before it is less than that placed after it.
Thus $12 < 16$ reads 12 is less than 16.

$>$ is used to signify the words greater than. Thus
> 12 reads 16 is greater than 12.

° Sign of degrees, as 62°—read sixty-two degrees.

Sign of minutes, as 52′—read fifty-two minutes.

″ Sign of seconds, 14″—read fourteen seconds.

′ Sign of feet, as 6′—read six feet.

″ Sign of inches as 9″—read nine inches.

π The greek letter pie signifies the ratio of the circum-
ence of a circle to its diameter and is equal to 3.1416
feet.

. The decimal point, as 12.6 feet—read twelve and six
nths feet—as 12.63 feet, read twelve and sixty three
ndredths feet.

□ Is used in place of the word square.

△ Is used in place of the word triangle.

± Is used in place of words plus and minus.

∺ Sign of geometrical proportion.

MULTIPLICATION.

Short Methods.

TO MULTIPLY ANY NUMBER FROM 10 TO 99 INCLUSIVE BY 11.

If the sum of the figures or digits composing the number is less than 10, add them and place the sum between the digits or figures of the number.

EXAMPLE.—Multiply 26 by 11.

The sum of the two figures 2 and 6 is 8.

Placing 8 between the two figures of the number we have 2-8-6 or 286 as the product of 26 by 11.

If the sum of the digits or figures composing the number is 10 or more, write down the right hand figure of the number to be multiplied by 11, next to it on the left place the right hand figure of the sum of the two digits composing the number, and next left, place the sum of 1 plus the left hand figure of the number to be multiplied by 11 and the figures thus placed will be the product required.

EXAMPLE.—Multiply 57 by 11.

Right hand figure,	7
Right hand figure of sum of digits,	2
Left hand figure plus 1,	6

∴ we have 627 as the product of 57 by 11.

TO MULTIPLY ANY NUMBER BY 11.

RULE.—Write the first right hand figure, add the first and second, place the sum to the left, add the second and third, place the sum next to the left and so on, and finally write the left hand figure of the number carrying as usual when sum is over 9.

EXAMPLE.—Multiply 58942 by 11.

Right hand figure,	2
1st + 2d figure,	6
2d + 3d figure, (carrying 1,)	3
3d + 4th + 1 carried, (carrying 1,)	8
4th + 5th + 1 carried, (carrying 1,)	4
Left hand figure + 1 carried,	6

∴ *we have 648362* as the product of 58942 by 11.

To Multiply by Any Number of Two Figures Ending in 1.

Write as the first figure of the product the right ha figure of the multiplicand (number multiplied). Mu ply each figure of the multiplicand by the left ha figure of the multiplier and at the same time a mentally to each product, the figure to the left of t one multiplied, carrying as usual.

Example.—Multiply 246 by 51.

Right hand figuıe of number,	6
$(5 \times 6) + 4 = 34$. Write 4 and carry 3,	4
$(5 \times 4) + 3$, car'd, $+ 2 = 25$. Write 5, carry 2,	5
$(5 \times 2) + 2$, car'd, $+ 0$ (no left hand fig.,) $=$	12

∴ we have 12,546 as the product of 246 by 51.

To Multiply by Any Number Between 12 and 20

Rule.—Multiply by the right hand figure of t multiplier and write the product under the mutiplica one place to the right and add.

Example.—Multiply 272 by 18.

Writing down the number we have	272
Multiplying mentally by 8 and placing product one figure or place to the right we have	2,176
And we have for the product;	4,896

To Multiply by Any Number Ending in 9.

Rule.—Multiply by one more than the given mu plier and from the result subtract the multiplicand the number multiplied.

Example.—Multiply 476 by 99.

476 by 100 =	47,600
Number multiplied,	476
Subtracting we have,	47,124

To Multiply by Any Multiple of 9 Less Than 90

Rule.—Multiply by the multiple of 10 next high than the given multiplier and from the result subtr one tenth of itself.

Example.—Multiply 263 by 54.

263 by 60, (mentally) =	15,780
$\frac{1}{10}$ of result, (move one place to right,)	1,578
Subtracting we have,	14,202

as the product of 263 by 54.

To Multiply by 25.

Rule.—Add two ciphers and divide the result by 4, or divide the number by 4; and add too ciphers. If there is a remainder of 1 add 25, of 2 add 50, of 3 add 75, etc.

To Multiply Any Number Ending in 5 Between 15 and 95 Inclusive by Itself.

Rule.—Write down for right hand figures, 25. Multiply left hand figure of number by next highest digit.

Example.—35 by 35.

Write down	25
3, left hand figure, by 4 =	12

We have for the product, 1225.

To Multiply by 50.

Rule.—Add two ciphers to the number and divide by 2, mentally.

To Multiply by $\frac{1}{25}$ or to Divide by 25.

Multiply by 4 and cut off two figures from the right of the result, or more accurately place decimal point between 2d and 3d figures of the result counting from the right.

Multiplication Table to 25 × 25.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75
4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147	154	161	168	175
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	200
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	225
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250
11	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176	187	198	209	220	231	242	253	264	275
12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300
13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260	273	286	299	312	325
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308	322	336	350
15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375
16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320	336	352	368	384	400
17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340	357	374	391	408	425
18	36	54	72	90	108	126	144	162	180	198	216	234	252	270	288	306	324	342	360	378	396	414	432	450
19	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361	380	399	418	437	456	475
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500
21	42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420	441	462	483	504	525
22	44	66	88	110	132	154	176	198	220	242	264	286	308	330	352	374	396	418	440	462	484	506	528	550
23	46	69	92	115	138	161	184	207	230	253	276	299	322	345	368	391	414	437	460	483	506	529	552	575
24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600
25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Apothecaries Weight.

The grain, ounce and pound used in Apothecaries weight are equal to those of Troy weight, the grain being used collectively as follows:

Table No. 3.

20 grains	= 1 scruple.			
3 scruples	= 1 dram	= 60 grains.		
8 drams	= 1 ounce	= 24 scruples	= 480 grains.	
12 ounces	= 1 pound	= 96 drams = 288 scruples	= 5,760 grains.	

For Apothecaries Fluid Measure, See Table No. 37.

Commercial or Avoirdupois Weight. (U. S. & Brit.)

The Commercial Pound or Pound Avoirdupois, which is the pound in common or commercial use is equal to the weight of 27.68122 cubic inches of pure distilled water at its maximum density (about 39. 2°Fahr.) when weighed at sea level in the latitude of London with barometer at 30".

It is equal to the weight of one-tenth of an Imperial Gallon of pure distilled water under above conditions of temperature, latitude and barometer or to 7000 grains Troy. For weighing all commodities except gold, silver, precious stones and drugs or medicines in small quantities, the following Table is in general use in the United States and Great Britian.

Table No. 4.

27.34375 grains	= 1 dram.		
16 drams	= 1 ounce	= 437½ grains.	
16 ounces	= 1 pound	= 7000 grains.	
100 pounds	= 1 hundredweight (cwt.) United States.		
20 cwt.	= 1 short ton	= 2000 pounds.	

In collecting duties upon foreign goods at United States Custom houses, freighting coal and selling it by wholesale, in buying cast iron pipe from some manufacturers, the Long Ton or 2240 pounds is used and is divided as follows:

Table No. 5.

14 pounds	= 1 stone.
2 stone	= 1 quarter.
4 quarters	= 1 hundredweight.
20 hundredweight	= 1 long ton.
1 *quintal*	= 100 pounds.

WEIGHTS.

The Legal Standard Pound of the United ... the Troy Pound of the Philadelphia Mint.

It is an exact copy of the Imperial Troy ... Great Britain and is equal to the weight of 22. ... inches of pure distilled water at the temperat... with barometer at 30".

For convenience the Troy pound is divi... [illegible] parts called grains, and used collect... follows.

Table No. 1.

Troy Weight (U. S. and British.)

24 grains	= 1 pennyweight, dwt	
20 pennyweights	= 1 ounce.	
12 ounces	= 1 pound	= 5760 gr.

For Foreign Weights and Measures, freq... in commercial relations with U. S. equiva... Tables No. [illegible] and [illegible]

Table No. 2.

Reduction Table With Equivalents [illegible]

Grains	Dwts.	Ozs.	Lbs.
1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	.05	[illegible]
	[illegible]	1	[illegible]
		[illegible]	1

Table No. 6.

REDUCTION TABLE WITH EQUIVALENTS IN GRAMS.

27.34375 grains equals, 1 dram.

Drams.		Ozs.		Lbs.		Qrs.		Cwts.		Gross Ton.		Fr Gr
1	=	.0625	=	.0039	=	.000139	=	.000035	=	.00000174	=	1.7
16	=	1	=	.0625	=	.00223	=	.000558	=	.000028	=	28.
256	=	16	=	1	=	.0357	=	.00893	=	.000447	=	453
7168	=	448	=	28	=	1	=	.25	=	.0125	=	127
28672	=	1792	=	112	=	4	=	1	=	.05	=	508
573440	=	35840	=	2240	=	80	=	20.	=	1	=	101

The grain is the same in Troy, Apothecaries Commercial weights.

For Foreign Weights and Measures frequently u in commercial relations with United States equivale see Tables No. 42 and 43.

Table No. 7.

REDUCTION TABLE.—OUNCES TO A DECIMAL OF A POU

Ozs.		Lbs.	Ozs.		Lbs.	Ozs.		Lbs.	Ozs.		L
¼	=	.015625	3	=	.1875	6½	=	.4063	11	=	
½	=	.03125	3½	=	.21875	7	=	.4375	12	=	
¾	=	.046875	4	=	.25	7½	=	.4688	13	=	
1	=	.0625	4½	=	.2813	8	=	.5	14	=	
1½	=	.09375	5	=	.3125	8½	=	.5313	15	=	
2	=	.125	5½	=	.3438	9	=	.5625	16	=	1
2½	=	.15625	6	=	.375	10	=	.625			

Table No. 8.

MULTIPLIERS FOR FACILITATING CALCULATIONS.

deposited in the Palais des Archives as the unit of weight of the Metric System.

It was supposed to be just equal to the weight of a cubic decimeter of pure distilled water at its maximum density in vauco at sea level in the latitude of Paris with barometer at 29.922°. It is not actually equal to it.

One Kilogram is equal to 2.2046 Commercial pounds or 2.679 Troy pounds.

For convenience the Kilogram is divided into 1000 parts called Grams and these again into 1000 parts called Milligrams. With Milligrams as a base the following table has been arranged for use in weighing similar commodites to those weighed by Commercial weight, and called

Table No. 9.

Table of Metric Measures of Weight.

10 milligrams = 1 centigram.
10 centigrams = 1 decigram.
10 decigrams = 1 gram.
10 grams = 1 decagram.
10 decagrams = 1 hectogram.
10 hectograms = 1 kilogram =
1,000 grams = 1,000,000 milligrams.
10 kilograms = 1 myriagram.
10 myriagrams = 1 French quintal.*
10 quintaux (quintals) = 1 Tonnea (tonne) or millier.

Table No. 10.

Table of Equivalents.

Metric or French Weight.		Commercial or Avoirdupois Weight, United States and British. Grains.	Ounces.	Pounds.	Tons.	Gross Tons.
1 Milligram	=	.0154				
1 Centigram	=	.1543	.0003			
1 Decigram	=	1.5432	.0035	.0002		
1 Gram †	=	15.4323	.0352	.0022		
1 Decagram	=	154.3234	.3527	.022		
1 Hectogram	=	1543.2348	3.5273	.2204	.0001	.000098
1 Kilogram	=	15432.3487	35.2736	2.2046	.0011	.00098
1 Myriagram	=		352.736	22.046	.011	.00984
1 Quintal*	=		3527.36	220.46	.1102	.09842
1 Tonnea or Milier	=		35273.6	2204.6	1.1023	.9842

† United States Standard = 15.432 grains. One 5 cent nickel = 5 grams, by law.

* *One Commercial* or Avoirdupois quintal = 100 lbs.

Table No. 10A.

TABLE OF EQUIVALENTS:

Metric or French Weight.		Troy Weight, U. S. and British. Dwts.	Ounces.	Pounds.
1 Milligram	=	.00064	.00003	
1 Centigram	=	.00643	.0003	
1 Decigram	=	.0643	.00321	
1 Gram	=	.643	.03215	
1 Decagram	=	6.43	.3215	
1 Hectogram	=	64.3	3.215	
1 Kilogram	=	643.0	32.15	2.679

Table No. 11.

TABLE OF EQUIVALENTS.

U. S. and British.		Metric or French.	
Grain	=	.064799	Grams.
Dwt.	=	1.555	"
Dram	=	1.771846	"
Ounce, Troy	=	31.1035	"
Ounce, Commercial	=	28.3496	"
Pound, Commercial	=	453.59	"
Pound, Troy	=	373.226	"
Pound, Commercial	=	.4536	Kilogram.
Pound Troy	=	.3732	"
Cwt.(112 lbs.)	=	50.8	"
Gross Ton	=	1016.06	"
Short Ton	=	907.2	"
Cross Ton	=	1.016	Tonneau or Metric Ton.
Short Ton	=	.9072	" " " "

APPROXIMATE EQUIVALENTS.

1 gram = 15½ grains.
1 kilogram = 2⅕ pounds.
1 tonnea = 2200 pounds.

For Foreign Weights and Measures frequently used in commercial relations with United States Equivalents, see Tables 42 and 43.

Note.—In this work British measures of length are considered equal to United States measures. The British are shorter by one part in 17230 or 3.677 inches per mile.

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supposed to be just equal to the weight of a
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n vauco at sea level in the latitude of Paris
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led Grams and these again into 1000 parts
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table has been arranged for use in weighing
ommodites to those weighed by Commercial
ınd called

Table No. 9.

ABLE OF METRIC MEASURES OF WEIGHT.

rams = 1 centigram.
rams = 1 decigram.
ams = 1 gram.
s = 1 decagram.
rams = 1 hectogram.
rams = 1 kilogram =
1,000 grams = 1,000,000 milligrams.
ams = 1 myriagram.
grams = 1 French quintal.*
aux (quintals) = 1 Tonnea (tonne) or millier.

Table No. 10.

TABLE OF EQUIVALENTS.

French		Commercial or Avoirdupois Weight, United States and British. Grains.	Ounces.	Pounds.	Tons.	Gross Tons.
	=	.0154				
	=	.1543	.0005			
	=	1.5432	.0035	.0002		
	=	15.4323	.0352	.0022		
	=	154.3234	.3527	.022		
	=	1543.2348	3.5273	.2204	.0001	.000098
	=	15432.3487	5736	2.2046	.0011	.00098
			736	22.046	.011	.00984
			.36	220.46	.1102	.09842
			1.6	2204.6	1.1023	.9842

grains. One 5 cent nickel =

quintal = 100 lbs.

Table No. 14.

LINEAL OR LONG MEASURE. (METRIC OR FRECNH SYSTEM.)

Metric or French.		United States or British Equivalents			
		Inches.	Feet.	Yards.	Miles.
	1 millimeter	= .03937	.00328		
10 millimeters	= 1 centimeter	= .39370428	.032809		
10 centimeters	= 1 decimeter	= 3.93704	.328086	.1093623	
10 decimeters	= 1 meter	= 39.370428	3.2808	1.0936	
10 meters	= 1 decameter	= 393.70428	32.8086	10.93623	
10 decameters	= 1 hectometer	= 3937.042	328,086	109.3623	.0621375
10 hectometers	= 1 kilometer	= 39370.42	3280.86	1093.623	.621375
10 kilometers	= 1 myriameter	= 393704.2	32808.6	10936.23	6.21375

Hectometer, Kilometer and Myriameter are road measures.

APPROXIMATE EQUIVALENTS.

1 millimeter = $\frac{1}{25}$ of an inch.
1 centimeter = $\frac{3}{8}$ of an inch.
1 meter = 3 feet, 3 $\frac{3}{8}$ inches.

Table No. 15.

DECIMAL EQUIVALENTS OF FRACTIONS OF A LINEAL INCH.

8ths.

$\frac{1}{8}$ = .125
$\frac{2}{8}$ = .25
$\frac{3}{8}$ = .375
$\frac{4}{8}$ = .5
$\frac{5}{8}$ = .625
$\frac{6}{8}$ = .75
$\frac{7}{8}$ = .875

16ths.

$\frac{1}{16}$ = .0625
$\frac{3}{16}$ = .1875
$\frac{5}{16}$ = .3125
$\frac{7}{16}$ = .4375
$\frac{9}{16}$ = .5625
$\frac{11}{16}$ = .6875
$\frac{13}{16}$ = .8125
$\frac{15}{16}$ = .9375

32nds.

$\frac{1}{32}$ = .03125
$\frac{3}{32}$ = .09375
$\frac{5}{32}$ = .15625
$\frac{7}{32}$ = .21875
$\frac{9}{32}$ = .28125
$\frac{11}{32}$ = .34375
$\frac{13}{32}$ = .40625
$\frac{15}{32}$ = .46875
$\frac{17}{32}$ = .53125
$\frac{19}{32}$ = .59375
$\frac{21}{32}$ = .65625
$\frac{23}{32}$ = .71875
$\frac{25}{32}$ = .78125
$\frac{27}{32}$ = .84375
$\frac{29}{32}$ = .90625
$\frac{31}{32}$ = .96875

64ths.

$\frac{1}{64}$ = .015625
$\frac{3}{64}$ = .046875
$\frac{5}{64}$ = .078125
$\frac{7}{64}$ = .109375
$\frac{9}{64}$ = .140625
$\frac{11}{64}$ = .171875
$\frac{13}{64}$ = .203125
$\frac{15}{64}$ = .234375
$\frac{17}{64}$ = .265625
$\frac{19}{64}$ = .296875
$\frac{21}{64}$ = .328125
$\frac{23}{64}$ = .359375
$\frac{25}{64}$ = .390625
$\frac{27}{64}$ = .421875
$\frac{29}{64}$ = .453125
$\frac{31}{64}$ = .484375
$\frac{33}{64}$ = .515625
$\frac{35}{64}$ = .546875
$\frac{37}{64}$ = .578125
$\frac{39}{64}$ = .609375
$\frac{41}{64}$ = .640625
$\frac{43}{64}$ = .671875
$\frac{45}{64}$ = .703125
$\frac{47}{64}$ = .734375
$\frac{49}{64}$ = .765625
$\frac{51}{64}$ = .796875
$\frac{53}{64}$ = .828125
$\frac{55}{64}$ = .859375
$\frac{57}{64}$ = .890625
$\frac{59}{64}$ = .921875
$\frac{61}{64}$ = .953125
$\frac{63}{64}$ = .984375

Table No. 16.

LINEAL INCHES AND PARTS OF AN INCH, REDUCED TO DECIMAL FRACTIONS OF A LINEAL FOOT.

Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.	Lineal Inches.	Lineal Foot.
1/64	.001302083	1 7/8	.15625	6 1/2	.5416
1/32	.00260416	2	.1666	6 3/4	.5625
1/16	.0052083	2 1/8	.177083	7	.5833
1/8	.010416	2 1/4	.1875	7 1/4	.60416
3/16	.015625	2 3/8	.197916	7 1/2	.625
1/4	.02083	2 1/2	.2083	7 3/4	.64583
5/16	.0260416	2 5/8	.21875	8	.66666
3/8	.03125	2 3/4	.22916	8 1/4	.6875
7/16	.0364583	2 7/8	.239583	8 1/2	.7083
1/2	.04166	3	.25	8 3/4	.72916
9/16	.046875	3 1/4	.27083	9	.75
5/8	.052083	3 1/2	.2916	9 1/4	.77083
11/16	.0572916	3 3/4	.3125	9 1/2	.7916
3/4	.0625	4	.33333	9 3/4	.8125
13/16	.0677083	4 1/4	.35416	10	.83333
7/8	.072916	4 1/2	.375	10 1/4	.85416
15/16	.078125	4 3/4	.39583	10 1/2	.875
1	.0833	5	.4166	10 3/4	.89583
1 1/8	.09375	5 1/4	.4375	11	.9166
1 1/4	.10416	5 1/2	.4583	11 1/4	.9375
1 3/8	.114583	5 3/4	.47916	11 1/2	.9583
1 1/2	.125	6	.5	11 3/4	.97916
1 5/8	.135416	6 1/4	.52083	12	1.000
1 3/4	.14583				

To reduce Lineal inches etc. to decimal fractions of a Lineal yard—divide any decimal corresponding as above given by 3.

Table No. 17.

SURVEYOR'S MEASURE.

7.92 inches = 1 link.
100. links = 1 chain (Gunthers).
80. chains = 1 mile (statute or land mile.)

The above table is sometimes used by "Country Surveyors" in tracing out old land lines, but is practically obselete and not used at all in the modern practice of the civil engineer.

Civil engineers *divide* the foot decimally and use a *100 foot chain.*

Mechanical Engineers, as a rule, divide the decimally.

Artificers sometimes divide the inch into lines twelfths, but the rule is to divide it into halves, quar eighths, sixteenths, thirty-seconds, sixty-fourths or o binary divisions.

Table No. 18.

Surveyor's Measure.

Reduction Table with Equivalents in the Metric or French System.

Inches.	Links.	Feet.	Yards.	Chains.	Miles.	Met
1.	.126	.0833	.0278	[illegible]	[illegible]	
7.92	1.	.66	.22	.01	.000125	
12	1.515	1.	.333	.01515	[illegible]	
36.	[illegible]	[illegible]	1.	.04545	[illegible]	
792.	100.	66.	22.	1.	.0125	20
63360.	8000.	5280.	1760.	80.	1.	1609

Table No. 19.

Circular or Angular Measure.

60 seconds (″) — 1 minute. (′)
60 minutes — 1 degree. (°)
360 degrees — 1 circumference. (C)

The Knot.

A nautical, geographical or sea mile is called a K and it is the length of one minute of longitude, latit

Table No. 22.

LENGTHS OF A DEGREE OF LONGITUDE IN DIFFERENT LATITUDES AT SEA LEVEL.

Deg. of Lat.	Statute Miles.	Deg. of Lat.	Statute Miles.	Deg. of Lat.	Statute Miles.	Deg. of Lat.	Statute Miles.
0	69.16	20	65.02	40	53.05	60	34.67
2	69.12	22	64.15	42	51.47	62	32.55
4	68.99	24	63.21	44	49.83	64	30.4
6	68.78	26	62.2	46	48.12	66	28.21
8	68.49	28	61.11	48	46.36	68	25.98
10	68.12	30	59.94	50	44.54	70	23.72
12	67.66	32	58.7	52	42.67	72	21.43
14	67.12	34	57.39	54	40.74	74	19.12
16	66.5	36	56.01	56	38.76	76	16.78
18	65.8	38	54.56	58	36.74	78	14.42

The above are only very close approximations as the exact shape of the earth is not known. Other lengths than those above given can be found by simple proportion. One degree of longitude corresponds to four minutes of clock time. One minute of longitude to four seconds of clock time.

Table No. 23.

FOREIGN MEASURES OF LENGTH FREQUENTLY USED IN COMMERCIAL RELATIONS WITH THEIR UNITED STATES EQUIVALENTS.

(Also see Table No. 43.)

Denomination.	Where Used.	U. S. Equivalent.	
Arshine,	Russia,	28.	inches.
Bu,	Japan,	.1	inch.
Chih,	China,	14.	inches.
Cuadra,	Paraguay,	78.9	yards.
Ken,	Japan,	6.	feet.
Li,	China,	2.115	feet.
Mil,	Denmark,	4.68	miles.
Mil, (geographical),	Denmark,	4.61	miles.
Milla,	Nicaragua and Honduras,	1.1493	miles.
Pic,	Egypt,	21.25	inches.
Pie,	Argentine Rep.,	.9478	foot.
Pie,	Castile, (Madrid, Spain)	.91407	foot.
Pik,	Turkey,	27.9	inches.
Sagen,	Russia,	7.	feet.

(Table continued on next page.)

Table No. 23. (Continued.)

Denomination.	Where Used.	U. S. Equivalent.
Shaku.	Japan,	11.9305 inches.
Sun.	Japan,	1.193 "
Tsun.	China,	1.41 "
Vara.	Argentine Republic,	34.1208 "
"	Castile, (Madrid, Spain)	.914117 yard.
"	Central America,	32.87 inches.
"	Chile and Peru,	33.367 "
"	Cuba,	33.384 "
"	Curacao,	33.375 "
"	Mexico,	33. "
"	Paraguay,	34. "
"	Venezuela,	33.384 "
Verst,	Russia,	.663 mile.

Table No. 24.

Square or Land Measure.

144 square inches	=	1 square foot, (sq. ft.)
100 square feet	=	1 square.
9 square feet	=	1 square yard, (sq. yd.)
30¼ square yards	=	1 square rod.
40 square rods	=	1 rood.
4 roods	=	1 acre.
640 acres	=	1 square mile.

A section of land is one mile square or 27,878,400 square feet, = 3,097,600 square yards or 640 acres. A

[redacted]

1 square acre is 208.71 feet square or on a side.
1 square ½ acre is 147.581 feet square or on a side.
1 square ¼ acre is 104.355 feet square or on a side.
1 circular acre is 235.504 feet in diameter.
1 circular ½ acre is 166.527 feet in diameter.
1 circular ¼ acre is 117.752 feet in diameter.
1 square foot = 183.346 circular inches.
1 square inch, = 1.27324 circular inches.
1 circular inch = .005454 square foot.
1 circular inch = .7854 square inch = a circle 1 inch in diameter.
Square feet × 2.3 = square links.
Square links × .4356 = square feet.
Square miles × 2.59 = square kilometers.

Table No. 26.

SQUARE OR LAND MEASURE. (METRIC OR FRENCH SYSTEM.)

Metric or French.

The unit			= 1 square millimeter.	
100	square	millimeters	= 1 "	centimeter.
100	"	centimeters	= 1 "	decimeter.
100 10,000	" "	decimeters centimeters	= 1 "	meter, (centiare).
100	"	meters	= 1 "	decameter, (are).
100	"	decameters	= 1 hectare, (square hectometer).	
100	"	hectometers	= 1 square kilometer.	
100	"	kilometers	= 1 "	myriameter.

United States or British Equivalents.

	Square Inches.	Square Feet.	Square Yards.	Acres.	Square Miles.
1 sq. millimeter	=.00155	.00001076	.0000012		
1 sq. centimeter	=.155003	.00107641	.0001196		
1 sq. decimeter	=15.5003	.107641	.01196		
1 sq. meter, (centiare)	=1550.03	10.7641	1.196	.000247	
1 sq. decameter, (are)	=155003.	1076.41	119.6011	.024711	
1 hectare (sq. hectom't'r) =		107641.	11960.1	2.4711	
1 sq. kilometer =		10764101.	1196011.	247.11	.386109
1 sq. myriameter =				24711.	38.6109

In France the "are" or square decameter is the unit of square or land measure and the following table is used:

Table No. 27.

1 milliare = $\frac{1}{1000}$th of a square decameter.
1 centiare = $\frac{1}{100}$th of a square decameter.
1 deciare = $\frac{1}{10}$th of a square decameter.
1 are = 1 square decameter.
1 decare = 10 ares or square decameters.
1 hectare = 100 ares or square decameters.

The United States and British equivalents for Table No. 27 are either given in Table No. 26 or easily obtained therefrom by properly moving the decimal point.

One square inch = 645.137 square millimeters.

For other United States and British equivalents of ... see Reduction Table. (Table No. 25.)

Table No. 28.

SQUARE INCHES IN DECIMAL FRACTIONS OF A SQUARE FOOT.

In.	Sq. Ft.	Sq. In.	Sq. Ft.	Sq. In.	Sq. Ft.	Sq. In.	Sq
	[illegible]	24.	.16666	65.	.45138	105.	.
	[illegible]	25.	.17361	66.	.45833	106.	.
	[illegible]	26.	.18055	67.	.46527	107.	.
	[illegible]	27.	.1875	68.	.47222	108.	.
	[illegible]	28.	.19444	69.	.47916	109.	.
	[illegible]	29.	.20138	70.	.48611	110.	.
	[illegible]	30.	.20833	71.	.49305	111.	.
	[illegible]	31.	.21527	72.	.5	112.	
	[illegible]	32.	.22222	73.	.50694	113.	.
	[illegible]	33.	.22916	74.	.51388	114.	.
	[illegible]	34.	.23611	75.	.52083	115.	
	[illegible]	35.	.24305	76.	.52777	116.	
	[illegible]	36.	.25	77.	.53472	117.	
	[illegible]	37.	.25694	78.	.54166	118.	
	[illegible]	38.	.26388	79.	.54861	119.	
	[illegible]	39.	.27083	80.	.55555	120.	
	[illegible]	40.	.27777	81.	.56249	121.	
	[illegible]	41.	.28472	82.	.56944	122.	
	[illegible]	42.	.29166	83.	.57638	123.	
	[illegible]	[illegible]	[illegible]	84.	[illegible]	124.	

Table No. 29.

ECIMAL FRACTIONS OF A SQUARE FOOT IN SQUARE INCHES.

q.Ft.	Sq. In.	Sq. Ft.	Sq. In.	Sq. Ft.	Sq. In.	Sq.Ft.	Sq. In.
1	1.44	.26	37.4	.51	73.4	.76	109.4
2	2.88	.27	38.9	.52	74.9	.77	110.9
3	4.32	.28	40.3	.53	76.3	.78	112.3
4	5.76	.29	41.8	.54	77.8	.79	113.8
5	7.2	.3	43.2	.55	79.2	.8	115.2
6	8.64	.31	44.6	.56	80.6	.81	116.6
7	10.1	.32	46.1	.57	82.1	.82	118.1
8	11.5	.33	47.5	.58	83.5	.83	119.5
9	13.	.34	49.	.59	85.	.84	121.
	14.4	.35	50.4	.6	86.4	.85	122.4
1	15.8	.36	51.8	.61	87.8	.86	123.8
2	17.3	.37	53.3	.62	89.3	.87	125.3
3	18.7	.38	54.7	.63	90.7	.88	126.7
4	20.2	.39	56.2	.64	92.2	.89	128.2
5	21.6	.4	57.6	.65	93.6	.9	129.6
6	23.	.41	58.	.66	95.	.91	131.
7	24.5	.42	60.5	.67	96.5	.92	132.5
8	25.9	.43	61.9	.68	97.9	.93	133.9
9	27.4	.44	63.4	.69	99.4	.94	135.4
	28.8	.45	64.8	.7	100.8	.95	136.8
1	30.2	.46	66.2	.71	102.2	.96	138.2
2	31.7	.47	67.7	.72	103.7	.97	139.7
3	33.1	.48	69.1	.73	105.1	.98	141.1
4	34.6	.49	70.6	.74	106.6	.99	142.6
5	36.	.5	72.	.75	108.	1.	144.

Table No. 30.

OREIGN SQUARE OR LAND MEASURES FREQUENTLY USED IN COMMERCIAL RELATIONS WITH THEIR UNITED STATES UQUIVALENTS.

rshine,(sq.)	Russia,	5.44	sq. feet.
ouw,	Sumatra,	7096.5	sq. meters.
uadra,	Argentine Rep.	4.2	acres.
"	Paraguay, (sq.)	8.077	sq. feet.
"	Uruguay,	2.	acres. (nearly)
essiatine	Russia,	2.6997	acres.
eddan,	Egypt,	1.03	"
ch,	Austria-Hungary,	1.422	"
eague(land)	Paraguay,	4633.	"
anzana,	Costa Rica,	1.8333	"

(*Table continued on next page.*)

Table No. 30. (Continued.)

Manzana,	Nicaragua and Salvador,	1.727	acres.
Morgen,	Prussia,	.63	"
See,	Japan,	.02451	"
Suerte,	Uruguay,	2700.	cuadras.
Tan,	Japan,	.25	acres.
Tondeland,	Denmark,	1.36	"
Tsubo,	Japan,	6.	ft. square.
Tunnland,	Sweden,	1.22	acres.
Vergees,	Russia,	71.1	sq. rods.
Vlocka,	Russian Poland,	41.98	acres.

Table No. 31.

CUBIC OR SOLID MEASURE. (U. S. AND BRITISH.)

1728 cubic inches = 1 cubic foot, (cu. ft.)
27 cubic feet = 1 cubic yard, (cu. yd.)

A cord of wood = 128 cubic feet and is in dimension = 4 feet wide by 4 feet high by 8 feet long or of such other dimensions as will give 128 cubic feet.

1 cord = 3.624 Steres, Metric or French system of solid measure.

In some western states, as California, 64 cubic feet or one-half United States cord is called one cord.

A perch of stone is supposed to be one rod long, one foot high and one and one-half feet wide or thick and contains 24.75 cubic feet.

It is generally taken at 25 cubic feet.

In Philadelphia, 22 cubic feet = 1 perch.

In parts of New England, 16.5 cubic feet = 1 perch.

The perch is not used by engineers and should not be used by anybody unless its amount in cubic feet is also specified.

The toise of Canada = 261.5 cubic feet.

The chaldron of Canada = 58.64 cu. feet.

Unit of reservoir and water shed capacity = 1 acre foot = one acre one foot deep = 43560 cubic feet.

Second feet = cubic feet per second.

California miners inch = .02 cubic foot per second = 8.976 gallons per minute = 12926.33 gallons per day.

In other places the miners inch varies from 10 to 12 gallons per minute.

For foreign weights and measures, frequently used in commercial relations with United States equivalents see Tables No. 42 and 43.

Table No. 32.

ONE CUBIC YARD EQUALS IN

tates es.	English Imperial Liquid and Dry Measures.		Metric or French Measures.	
c inches.	168.266	gallons.	.0764534	myrioliter or de-
: feet.	84.13	pecks.		castere.
id gallons	21.033	bushels.	.764534	kiloliter, cu. me-
id barrels.	5.258	coombs.		ter or stere.*
r barrels.	2.629	quarters.	7.64534	hectoliters or de-
ped bushels.				cisteres.
ck bushels			76.4534	decaliters or cen-
ts.				tisteres.
			764.534	liters† or cubic
				decimetres.
			7645.34	deciliters.

Table No. 33.

ONE CUBIC FOOT EQUALS IN

tates res.	English Imperial Liquid and Dry Measures.		Metric or French Measures.	
ic inches.	199.427	gills.	.002832	myrioliter or deca-
ndrical ins.	49.8568	pints.		stere.
ic yard.	24.928	quarts.	.028316	kiloliter, cu. meter
.id gills.	12.464	pottles.		or stere.*
id pints.	6.232	gallons.	.28316	hectoliter or decis-
.id quarts.	3.116	pecks.		tere.
.id gallons.	.779	bushel.	2.8316	decaliters or centis-
pints.	.194	coomb.		teres.
quarts.	.097	quarter.	28.316	liters† or cu. deci-
gallons.				meters.
ks.			283.16	deciliters.
uck bushel.			2831.6	centiliters.
ped bushel.			28316.	milliliters or cubic
.r barrel.				centimeters.
iid barrel.				

Table No. 34.

ONE CUBIC INCH EQUALS IN

states res.	English Imperial Liquid and Dry Measures.		Metric or French Measures.	
bic foot.	.0288	pint.	.000016386	stere,* cu. meter
bic yard.	.115	gill.		or kiloliter.
herical ins.	.0144	quart.	.0001638	decistere.
uid gill.	.0072	pottle.	.001638	centistere.
uid pint.	.0036	gallon	.01638	millisters, liter†
uid quart.	.0018	peck.		or cu. decimeter.
uid gallon.	.0045	bushel.	.16386	deciliter.
y pint.			1.6386	centiliters.
y quart.			16.386	milliliters or cu.
y gallon.				centimeters.
ck.			16386.	cubic millimeters
uck bushel.				
ped bushel.				

*The stere is unit of solid measure.

†The liter is unit of liquid measure.

Table No. 35.

Liquid Measure. (United States Only.)

The unit = 1 gill.
4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.

Table No. 36.

Reduction Table With Equivalents in Cub
Measure, Pounds of Water, and Liters.

Gills.	Pints.	Quarts.	Gallons.	Cu. Ins.	Lbs. Water. 70° Fahr.	L
1	.25	.125	.31	7.218	.26005	
4	1.	.5	.125	28.875	1.0402	
8	2.	1.	.25	57.75	2.0804	
32	8.	4.	1.	231.	8.3216	

To reduce to United States dry measure of the denomination, multiply by .8593 or divide by 1.1

To reduce to British Imperial Liquid or dry me of the same denomination multiply by .83 or divi 1.20032 or approximately by 1.2.

In the United States, 1 barrel = 31.5 gallons or cubic feet.

A Hogshead = two barrels or 63 gallons. The Hogshead is used to designate casks etc., of capacities, and should not be used in engineering.

Table No. 37.

Apothecaries Measures.

Table No. 39.

REDUCTION TABLE WITH EQUIVALENTS IN CUBIC MEASURE, POUNDS WATER AND LITERS.

Pints.	Qts.	Gals.	Pcks.	Struck Bushls.	Heap'd Bushls.	Cubic Inch's.	Pounds Water 70° Fahr.	Liters.
1.	.5	.125	.0625	.015625	.0125	33.6008	1.2104	.55
2.	1.	.25	.125	.03125	.025	67.2006	2.4208	1.1
8.	4.	1.	.5	.125	.1	268.8025	9.6834	4.4
16.	8.	2.	1.	.25	.2	537.605	19.367	8.802
						Cu. Ft.		
64.	32.	8.	4.	1.	.8	1.24445	77.467	35.208
80.	40.	10.	5.	1.25	1.	1.55556	96.83	44.01

To reduce to United States liquid measure of the same denomination multiply by 1.16365 or divide by .8593.

To reduce to British Imperial dry and liquid measures of the same denomination, divide by 1.031516 or multiply by .0969, or approximately by .097.

By law one struck bushel measure is 18.5 inches inner diameter, 19.5 inches outer diameter and 8 inches deep.

When heaped, the cone not less than 6 inches high (height of top of material or goods measured above top of measure) the bushel is called a heaped bushel and is equal to 1.25 struck bushels, as above mentioned.

A dry flour barrel contains 3.75 cubic feet = 3 struck bushels, but is not a legalized measure, though by law 196 pounds of flour is a barrel; 37.66 heaped bushels = 1 chaldron of Canada, (nearly).

For Foreign Weights and Measures, frequently used n commercial relations, with United States equivalents ee Tables No. 42 and 43.

Table No. 40.

BRITISH IMPERIAL LIQUID AND DRY MEASURE.—WITH EQUIVALENTS.

			Com. Pounds of Water.	Cubic Inches.	Cubic Feet.
gills	= 1 pint	=	1.25	34.6592	
pints	= 1 quart	=	2.5	69.3185	
quarts	= 1 pottle	=	5.	138.637	
pottles	= 1 gallon	=	10.	277.274	.16046
gallons	= 1 peck	=	20.	554.548	
pecks	= 1 bushel	=	80.	2218.192	1.2837
bushels	= 1 coomb	=	320.	8872.768	5.1347
coombs	= 1 quarter	=	640.	17745.536	10.2694

The Imperial Gallon = 1.20032 United States Liquid llons (or approximately $1\frac{1}{5}$ United States liquid llons) = 4.541 liters.

Table No. 41.

METRIC OR FRENCH CUBIC OR SOLID MEASURE, LIQUID AND DRY MEASURES WITH UNITED STATES AND BRITISH EQUIVALENTS.

	Cub. Ins.		
Milliliter, or cubic Centimeter	.061025	Liquid.	.008453 gill.
		"	.007043 Brit. gill.
		Dry.	.001816 dry pint.
Centiliter	.61025	Liquid.	.08453 gill.
		"	.07043 Brit. gill.
		Dry.	.01816 dry pint.
Deciliter	6.1025	Liquid.	.8453 gill = .2113 pint.
		"	.7043 Brit. gill.
		Dry.	.18162 dry pint.
Liter, or cubic Decimeter.	61.025	Liquid.	1.05671 quart.
		"	.88036 Brit. quart
		Dry.	.11351 peck = .908 dry quart.
Decaliter or Centistere	610.251 / Cub. Ft. .35316	Liquid.	2.64179 U. S. liquid gallons.
		"	2.2009 Brit. gallons.
		Dry.	.283783 bushels = 1.1351 peck.
Hectoliter, or Decistere	3.53166	Liquid.	26.4179 U. S. liquid gallons.
		"	22.009 Brit. gallons.
		Dry.	2.83783 bushels.
Kiloliter, or Cubic Meter* or Stere.	35.3156	Liquid.	264.179 U. S. liquid gallons.
		"	220.09 Brit. gallons.
		Dry.	28.3783 bushels.
Myrioliter or Decastere	353.156	Liquid.	2641.79 U. S. liquid gallons.
		Dry.	283.783 bushels.
			13.08 cubic yards.

* Cubic Meter = 1.308 cubic yards.

Except such equivalents as are marked "Brit." are given in United States measures.

Table No. 42.

FOREIGN WEIGHTS AND MEASURES FREQUENTLY USED IN COMMERCIAL RELATIONS.—WITH U.S. EQUIVALENTS.

Table No. 42. (Continued.)

ons.	Where Used.	United States Equivalents.
)	Spain,	140 gallons.
	Malta,	5.4 gallons.
	India (Bombay,)	529 pounds.
	India (Madras,)	500 pounds.
	Morocco,	113 pounds.
	Syria (Damascus,)	575 pounds.
	Turkey,	124.7036 pounds.
ntar,)	Malta,	175 pounds.
	Mexico and Salvador,	300 pounds.
	China,	1.33 pounds.
	Japan,	1.31 pounds.
	Java, Siam, and Malacca,	1.35 pounds.
	Sumatra,	2.12 pounds.
	Central America,	4.2631 gallons.
	Bremen and Brunswick,	117.5 pounds.
	Darmstadt,	110.24 pounds.
	Denmark and Norway,	110.11 pounds.
	Nuremberg,	112.43 pounds.
	Prussia,	113.44 pounds.
	Sweden,	93.7 pounds.
	Vienna,	123.5 pounds.
	Zollverein,	110.24 pounds.
	Double or metric.	220.46 pounds.
	Sarawak,	3098. pounds.
	Siam (Koyan,)	2667. pounds.
	Spain,	1.599 bushels.
	Greece,	Half ounce.
y,)	Central Amercia,	1.5745 bushels.
	Chile,	2.575 bushels.
	Cuba,	1.599 bushels.
	Mexico,	1.54728 bushels.
	Morocco.	Strike fanega, 70 lbs.; full fanega 118 lbs.
	Uruguay (double,)	7.776 bushels.
	Uruguay (single,	3.888 bushels.
	Venezuela,	1.599 bushels.
quid,)	Spain,	16 gallons.
ns,)	"	50 pounds.
	Argentine Republic.	2.5096 quarts.
	Mexico,	2.5 quarts.
	Zanzibar,	35 pounds.
	Luxemburg,	264.17 gallons.
	Russian Poland,	0.88 gallon.
	Russia.	216 cubic feet.
	Japan,	4.9629 bushels.
	Russia,	3.5 bushels.
	Japan,	8.28 pounds.

requently called "kin." Among merchants in the
s it equals 1.33⅓ pounds commercial.

(Table continued on next page.)

Table No. 42. (Continued.)

Denominations.	Where Used.	United States Equivalents.
Last.	Belgium and Holland.	85.134 bushels.
"	England (dry malt.)	82.52 bushels.
"	Germany.	2 metric tons (4,40[illegible] pounds.
"	Prussia.	112.29 bushels.
"	Russian Poland.	11¾ bushels.
"	Spain (salt.)	4,760 pounds.
Libra (pound.)	Castilian.	7100 grains (troy.)
"	Argentine Republic.	1.0127 pounds.
"	Central America.	1.043 pounds.
"	Chile.	1.014 pounds.
"	Cuba.	1.0161 pounds.
"	Mexico.	1.01465 pounds.
"	Peru.	1.0143 pounds.
"	Portugal.	1.011 pounds.
"	Uruguay.	1.0143 pounds.
"	Venezuela.	1.0161 pounds.
Liter.	Metric.	1.0567 quarts.
Livre (pound.)	Greece.	1.1 pounds.
"	Guiana.	1.0791 pounds.
Load.	England (timber.)	Square, 50 cub[illegible] feet; unhew[illegible] cubic feet; [illegible] planks, 600 su[illegible]ficial feet.
Mark.	Bolivia.	0.507 pound.
Maund.	India.	82.2857 pounds.
Oke.	Egypt.	2.7225 pounds.
	Greece.	2.84 pounds.
	Hungary.	3.0817 pounds.

Table No. 42. (Continued.)

inations.	Where Used.	United States Equivalents.
	Malta,	490 pounds.
	India,	1 pound 13 ounces.
	"	1.6 quarts.
ırd (St. 'etersburg,)	Lumber measure,	165 cubic feet.
	British,	14 pounds.
	Cochin China,	590.75 grains (troy
	"	2 pecks.
	Space measure,	40 cubic feet.
e (cereals,)	Denmark,	3.94783 bushels.
a,	Sweden,	4.5 bushels.
o,	Russia,	2.707 gallons.

Table No. 43.

EIGN WEIGHTS AND MEASURES WITH UNITED STATES APPROXIMATE EQUIVALENTS.

:incipal nations arranged alphabetically. For other ghts and measures see Table 42.

ARGENTINE CONFEDERATION.

etric system used in the assessment of duties. Old nish weights and measures (see Spain) in common

AUSTRIA, (SAME AS GERMANY.)

BELGIUM, (METRIC SYSTEM.)

BOLIVIA.

ıe metric system is the legal system, but the law not been rigidly enforced. Old Spanish weights measures (see Spain) still in use. For coin weight netric gram is used.

BRAZIL, (METRIC SYSTEM.)

ımonds are permitted to be sold according to the ortuguese "outava" (55.34 grains.)

ps' freights are for the most part, settled according English ton (2240 lbs.)

CANADA, (SAME AS GREAT BRITAIN.)

CHILE, (SAME AS BOLIVIA.)

custom purposes the metric system is enforced.

China.

1 tael	=	$1\frac{1}{4}$ ozs. commercial.
1 catty	=	$1\frac{1}{3}$ lbs. "
1 picul	=	$133\frac{1}{3}$ lbs. "
1 chih	=	14. inches.
1 chang	=	11.75 feet.

Columbia, (Metric System.)

Denmark.

1 pund ($\frac{1}{2}$ kilogram)	=	1.1023 lbs. commercial.
1 centner (100 lbs.)	=	110.11 lbs. "
1 tönde of grain	=	3.948 U. S. bushels.
1 tönde of coal	=	4.825 U. S. "
1 fod (foot)	=	1.03 U. S. ft.
1 viertel	=	2.04 U. S. gallons.
1 alen (ell)	=	.6864 yards.

Coinage laws are metric. Metric system of weights and measures is also used.

Ecuador, (Metric System.)

Egypt, (Metric System.)

France, (Metric System.)

The old French aune = $1\frac{1}{4}$ yds. is still used to some extent in the silk industries of France and the U. S.

Germany,

Metric system with a few changes in subdivisions is in general use.

India.

1 seer	= 16 chattucks.	
1 Bombay maund of 40 seers	= 28	lbs. commercial.
1 " " " 42 "	= 29.4	" "
1 Surat " " 40 "	= 31⅓	" "
1 " " " 42 "	= 39⅕	" "
1 " " " 44 "	= 41 1/15	" "
1 Bengal factory maund	= 74⅔	" "
1 " bazaar "	= 82 1/9	" "
1 Madras maund	= 25	" "
1 Bom'y candy of 20 maunds	= 560	" "
1 Surat " " "	= 746⅔	" "
1 Madras " " "	= 500	" "
1 Travancore " " "	= 660	" "
1 tola	= 180 grs.	
1 guz of Bengal	= 1 yard.	
1 corge	= 20 units.	
1 corge pound	= 20 lbs.	

Metric system permissive.

Italy.

1 palm = .555 cu. ft.

Metric system in general use.

Japan.

1 picul = 133⅓ lbs, commercial.

For coinage, in part, the metric unit of weight is used.

Java.

1 Amsterdam pond	= 1.09 lbs.	commercial.
1 picul	= 133⅓	"
1 catty	= 1⅓	"
1 chang	= 4 yards.	

Mexico.

Weights and measures are legally the metric, but the metric system is not generally in force. the old Spanish weights and measures (see Spain) being still employed.

Netherlands.

Metric system with a change in names in general use.

1 last (30 hectoliters) = 85.134 bushels.

Norway and Sweden.

1 Swedish skalpond	= .93⅓ lbs.	commercial.
1 Swedish centner	= 93⅓ lbs.	"
1 Norwegian pund	= 1.1 lbs.	"
1 Swedish *fot*	= 11.7 inches.	
1 *Norwegian fod*	= 12.02 "	

[illegible]

[illegible] October 1, 1898.

[illegible] :—

[illegible] = [illegible] lbs. commercial.

[illegible] = [illegible] U. S. gallons.

[illegible] = [illegible] U. S. bushels.

[illegible]

[illegible] = [illegible] lbs. commercial.

[illegible] = [illegible] " "

[illegible] = [illegible] " "

[illegible] = [illegible] U. S. bushels.

[illegible] = [illegible] U. S. gallons.

[illegible] = [illegible]

[illegible] = [illegible]

[illegible]

[illegible]

[illegible] States and in Cuba, [illegible] principally [illegible] follows:

[illegible] = [illegible] lbs. commercial.

[illegible] = [illegible] " "

[illegible] = [illegible] " "

[illegible] = [illegible]

[illegible]

[illegible] changes of names and [illegible] optional.

[illegible] (Metric System.)

[illegible] (CONFEDERATION.)

[illegible] (Metric System.)

Table No. 44.

[illegible] CURRENCIES.

[illegible] (United States Treasury) valuations of [illegible] "rates of exchange."

[illegible] U. S. Consular Report, Vol. LXIII, No. 239. Aug. 1, 1900.)

Countries.	Standard.	Monetary Unit.	Value in U.S. Gold.
[illegible]	Gold and Silver.	Peso.	$ .96,5
[illegible]	Gold.	Crown.	.20,3
[illegible]	Gold and Silver.	Franc.	.19,3
[illegible]	Gold.	Milreis.	.54,6
[illegible]	"	Dollar.	1.00
[illegible]	"	"	1.00
	"	Peso.	.36,5
	"	Colon.	.46,5

(Table continued on next page.)

Table No. 44. (Continued.)

tries.	Standard.	Monetary Unit.	Value in U.S.Gold.
	Gold and Silver,	Colon,	$ .92,6
k,	Gold,	Crown,	.26,8
	"	Pound (100 piasters),	4.94,3
	"	Mark,	.19,3
	Gold and Silver,	Franc,	.19,3
r,	Gold,	Mark,	.23,8
itain,	"	Pound Sterling,	4.86,6½
	Gold and Silver,	Drachma,	.19.3
	" "	Gourde,	.96.5
	" "	Lira,	.19,3
	Gold,	Yen,	.49,8
	"	Dollar,	1.00
nds.	Gold and Silver,	Florin,	.40,2
idland,	Gold,	Dollar,	1.01,4
,	"	Milreis,	1.08
	"	Ruble,	.51,5
	Gold and Silver,	Peseta,	.19,3
and Norway,	Gold,	Crown,	.26.8
and,	Gold and Silver,	Franc,	.19,3
	Gold,	Piaster,	.04,4
,	"	Peso,	1.03.4
a,	Gold and Silver,	Bolivar,	.19,3

Table No. 45.

TRIES WITH FLUCTUATING CURRENCIES, GIVING QUARTERLY VALUATIONS IN 1900.

ies.	Momentary Unit.	Jan. 1.	April 1.	July 1.
	Silver boliviano,	$ .42,7	$ .43,6	$ .43,8
America,	Silver peso,	.42,7	.43,6	.43,8
	Amoy tael,	.69,1	.70,5	.70,9
	Canton tael,	.68,9	.70,3	.70,7
	Chefoo tael,	.66,1	.67,4	.67,8
	Chinkiang tael,	.67,5	.68,8	.69,3
	Fuchau tael,	.64	.65,2	.65,6
	Haikwan tael,	.70,3	.71,7	.72,1
	Hankau tael,	.64,7	.65,9	.66,3
	Ningpo tael,	.66,5	.67,7	.68,2
	Niuchwang tael,	.64,8	.66,1	.66,5
	Shanghai tael,	.63,1	.64,4	.64,8
	Swatow tael,	.63,9	.65,1	.65,5
	Takao tael,	.69,6	.70,9	.71,4
	Tientsin tael,	.67	.68,3	.68,7
a,	Silver peso,	.42,7	.43,6	.43,8
,	"	.42,7	.43,6	.43,8
	Silver rupee,	.20,3	.20,7	.20,8
	Silver dollar,	.46,4	.47,3	.47,6
	Silver kran,	.07,9	.08	.08,1
	Silver sol,	.42,7	.43,6	.43,8

commercial value of the rupee to be determined by certificate.

which is written in the quotient. By subtracting this cube (27) from the left-hand period (46), and annexing to the remainder (19) the next period (656), we form the dividend, 19656. By multiplying the square of the root already found by 300 (multiply by 3 and add two ciphers), we form the trial divisor, 2700 ($300 \times 3^2 = 2700$). The trial divisor, 2700, is contained in the dividend, (19656) 6 times. Write 6 as the next figure of the root. To form the complete divisior, add to the trial divisior (2700) 30 times the product of the last figure (6) of the root and the other figure 3 ($30 \times 6 \times 3 = 540$), and the square of the last figure ($6^2 = 36$). Multiplying this complete divisor, 3276 by 6, the last figure of the root, and subtracting the product (19656) from the dividend (19656), there is no remainder, $\therefore$ 36 is the required cube root.

NOTE.—When the given number contains a decimal separate the number into periods of three figures each, by proceeding in both directions from the decimal point.

NOTE.—In finding the cube root of a fraction, when both are cubes extract the cube root of the numerator and denominator separately. When they are not, reduce to a decimal fraction and find its cube root.

USE OF CUBE ROOT.

A box contains 1728 cu. inches. What are its dimensions?

The cube root of 1728 = 12 inches. ($12 \times 12 \times 12 = 1728$.)

The solid contents of similar figures are to each other as the cubes of their similar dimensions—sides or diameters.

EXAMPLE:—If a ball 3" in diameter, weighs 4 pounds. What will a ball of same material weigh whose diameter is 6"?

Cube of similar dimensions, $3 \times 3 \times 3 = 27$. $6 \times 6 \times 6 = 216$.

$\therefore$ 27 : 4 lbs :: 216 : required weight.

$$\therefore \text{required weight} = \frac{216 \times 4}{27} = 32 \text{ lbs.}$$

EXAMPLE.—Having a box, $4' \times 4' \times 4' = 64$ cu. ft. ...ity, required the length of the side of another box that will hold 4 times as much.

$64 \times 4 = 256$, $\sqrt[3]{256} = 6.349$ ft. = side of the ...ed.

Table No. 46.

Square Roots and Cube Roots of Numbers From

.1 to 20

INCLUSIVE.

ables see pages 40 to 47 inclusive.

	q. Rt.	C. Rt.	No.	Sq. Rt.	C. Rt.	No.	Sq. Rt.	C. Rt.
	.316	.464	.4	2.098	1.639	.5	3.240	2.189
	.387	.531	.5	2.121	1.651	.6	3.256	2.197
	.447	.585	.6	2.145	1.663	.7	3.271	2.204
	.500	.630	.7	2.168	1.675	.8	3.286	2.211
	.548	.669	.8	2.191	1.687	.9	3.302	2.217
	.592	.705	.9	2.214	1.699	11.0	3.317	2.224
	.633	.737	5.0	2.236	1.710	.1	3.332	2.231
	.671	.766	.1	2.258	1.721	.2	3.347	2.237
	.707	.794	.2	2.280	1.733	.3	3.362	2.244
5	.742	.819	.3	2.302	1.744	.4	3.376	2.251
6	.775	.843	.4	2.324	1.754	.5	3.391	2.257
5	.806	.866	.5	2.345	1.765	.6	3.406	2.264
43	.837	.888	.6	2.366	1.776	.7	3.421	2.270
22	.866	.909	.7	2.388	1.786	.8	3.435	2.277
512	.894	.928	.8	2.408	1.797	.9	3.450	2.283
514	.922	.947	.9	2.429	1.807	12.0	3.464	2.289
729	.949	.965	6.0	2.450	1.817	.1	3.479	2.296
857	.975	.983	.1	2.470	1.827	.2	3.493	2.302
.000	1.000	1.000	.2	2.490	1.837	.3	3.507	2.308
.158	1.025	1.016	.3	2.510	1.847	.4	3.521	2.315
.331	1.049	1.032	.4	2.530	1.857	.5	3.536	2.321
.521	1.072	1.048	.5	2.550	1.866	.6	3.550	2.327
.728	1.095	1.063	.6	2.569	1.876	.7	3.564	2.333
.953	1.118	1.077	.7	2.588	1.885	.8	3.578	2.339
2.197	1.140	1.091	.8	2.608	1.895	.9	3.592	2.345
2.460	1.162	1.105	.9	2.627	1.904	13.0	3.606	2.351
2.744	1.183	1.119	7.0	2.646	1.913	.2	3.633	2.363
3.049	1.204	1.132	.1	2.665	1.922	.4	3.661	2.375
3.375	1.225	1.145	.2	2.683	1.931	.6	3.688	2.387
3.724	1.245	1.157	.3	2.702	1.940	.8	3.715	2.399
4.096	1.265	1.170	.4	2.720	1.949	14.0	3.742	2.410
4.492	1.285	1.182	.5	2.739	1.957	.2	3.768	2.422
4.913	1.304	1.194	.6	2.757	1.966	.4	3.795	2.433
5.359	1.323	1.205	.7	2.775	1.975	.6	3.821	2.444
5.832	1.342	1.216	.8	2.793	1.983	.8	3.847	2.455
6.332	1.360	1.228	.9	2.811	1.992	15.0	3.873	2.466
6.859	1.378	1.239	8.0	2.828	2.000	.2	3.899	2.477
7.415	1.396	1.249	.1	2.846	2.008	.4	3.924	2.488
8.000	1.414	1.260	.2	2.864	2.017	.6	3.950	2.499
9.261	1.449	1.281	.3	2.881	2.025	.8	3.975	2.509
10.65	1.483	1.301	.4	2.898	2.033	16.0	4.000	2.520
12.17	1.517	1.320	.5	2.916	2.041	.2	4.025	2.530
13.82	1.549	1.339	.6	2.933	2.049	.4	4.050	2.541
15.63	1.581	1.357	.7	2.950	2.057	.6	4.074	2.551
17.58	1.613	1.375	.8	2.967	2.065	.8	4.099	2.561
19.68	1.643	1.393	.9	2.983	2.072	17.0	4.123	2.571
21.95	1.673	1.409	9.0	3.000	2.080	.2	4.147	2.581
24.39	1.703	1.426	.1	3.017	2.088	.4	4.171	2.591
27.00	1.732	1.442	.2	3.033	2.095	.6	4.195	2.601
29.79	1.761	1.458	.3	3.050	2.103	.8	4.219	2.611
32.77	1.789	1.474	.4	3.066	2.111	18.0	4.243	2.621
35.94	1.817	1.489	.5	3.082	2.118	.2	4.266	2.630
39.30	1.844	1.504	.6	3.098	2.125	.4	4.290	2.640
2.88	1.871	1.518	.7	3.115	2.133	.6	4.313	2.650
6.66	1.897	1.533	.8	3.131	2.140	.8	4.336	2.659
0.65	1.924	1.547	.9	3.146	2.147	19.0	4.359	2.668
4.87	1.949	1.561	10.0	3.162	2.154	.2	4.382	2.678
9.32	1.975	1.574	.1	3.178	2.162	.4	4.405	2.687
4.00	2.000	1.587	.2	3.194	2.169	.6	4.427	2.696
8.92	2.025	1.601	.3	3.209	2.177	.8	4.450	2.705
4.09	2.049	1.613	.4	3.225	2.183	20.0	4.472	2.714
9.51	2.074	1.626						

contains parts of an inch get decimal equivalent
15 or 16.

[illegible]

No.	[illegible]	[illegible]	[illegible]	[illegible]	No.	[illegible]	[illegible]	Sq. Ft.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	772	28681	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	844	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	409	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	27465	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	436	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	449	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	452	31452	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9	472	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	490	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	641	35791	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	529	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	625	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	776	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	211	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51300	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	689	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	705	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	796	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	769	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	774	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table No. 46B.

E, CUBE, SQUARE ROOT AND CUBE ROOT OF EACH WHOLE NUMBER FROM

121 to 250

INCLUSIVE.

are	Cube.	Sq. Rt.	C. Rt.	No.	Square	Cube.	Sq. Rt.	C. Rt.
41	1771561	11.0000	4.9461	186	34596	6434856	13.6382	5.7083
84	1815848	11.0454	4.9597	187	34969	6539203	13.6748	5.7185
29	1860867	11.0905	4.9732	188	35344	6644672	13.7113	5.7287
76	1906624	11.1355	4.9866	189	35721	6751269	13.7477	5.7388
25	1953125	11.1803	5.0000	190	36100	6859000	13.7840	5.7489
76	2000376	11.2250	5.0133	191	36481	6967871	13.8203	5.7590
29	2048383	11.2694	5.0265	192	36864	7077888	13.8564	5.7690
84	2097152	11.3137	5.0397	193	37249	7189057	13.8924	5.7790
41	2146689	11.3578	5.0528	194	37636	7301384	13.9284	5.7890
00	2197000	11.4018	5.0658	195	38025	7414875	13.9642	5.7989
61	2248091	11.4455	5.0788	196	38416	7529536	14.0000	5.8088
24	2299968	11.4891	5.0916	197	38809	7645373	14.0357	5.8186
89	2352637	11.5326	5.1045	198	39204	7762392	14.0712	5.8285
56	2406104	11.5758	5.1172	199	39601	7880599	14.1067	5.8383
25	2460375	11.6190	5.1299	200	40000	8000000	14.1421	5.8480
96	2515456	11.6619	5.1426	201	40401	8120601	14.1774	5.8578
69	2571353	11.7047	5.1551	202	40804	8242408	14.2127	5.8675
44	2628072	11.7473	5.1676	203	41209	8365427	14.2478	5.8771
21	2685619	11.7898	5.1801	204	41616	8489664	14.2829	5.8868
00	2744000	11.8322	5.1925	205	42025	8615125	14.3178	5.8964
81	2803221	11.8743	5.2048	206	42436	8741816	14.3527	5.9059
64	2863288	11.9164	5.2171	207	42849	8869743	14.3875	5.9155
49	2924207	11.9583	5.2293	208	43264	8998912	14.4222	5.9250
36	2985984	12.0000	5.2415	209	43681	9129329	14.4568	5.9345
25	3048625	12.0416	5.2536	210	44100	9261000	14.4914	5.9439
16	3112136	12.0830	5.2656	211	44521	9393931	14.5258	5.9533
09	3176523	12.1244	5.2776	212	44944	9528128	14.5602	5.9627
04	3241792	12.1655	5.2896	213	45369	9663597	14.5945	5.9721
01	3307949	12.2066	5.3015	214	45796	9800344	14.6287	5.9814
00	3375000	12.2474	5.3133	215	46225	9938375	14.6629	5.9907
01	3442951	12.2882	5.3251	216	46656	10077696	14.6969	6.0000
04	3511808	12.3288	5.3368	217	47089	10218313	14.7309	6.0092
09	3581577	12.3693	5.3485	218	47524	10360232	14.7648	6.0185
16	3652264	12.4097	5.3601	219	47961	10503459	14.7986	6.0277
25	3723875	12.4499	5.3717	220	48400	10648000	14.8324	6.0368
36	3796416	12.4900	5.3832	221	48841	10793861	14.8661	6.0459
49	3869893	12.5300	5.3947	222	49284	10941048	14.8997	6.0550
64	3944312	12.5698	5.4061	223	49729	11089567	14.9332	6.0641
81	4019679	12.6095	5.4175	224	50176	11239424	14.9666	6.0732
00	4096000	12.6491	5.4288	225	50625	11390625	15.0000	6.0822
21	4173281	12.6886	5.4401	226	51076	11543176	15.0333	6.0912
44	4251528	12.7279	5.4514	227	51529	11697083	15.0665	6.1002
69	4330747	12.7671	5.4626	228	51984	11852352	15.0997	6.1091
96	4410944	12.8062	5.4737	229	52441	12008989	15.1327	6.1180
25	4492125	12.8452	5.4848	230	52900	12167000	15.1658	6.1269
56	4574296	12.8841	5.4959	231	53361	12326391	15.1987	6.1358
89	4657463	12.9228	5.5069	232	53824	12487168	15.2312	6.1446
24	4741632	12.9615	5.5178	233	54289	12649337	15.2643	6.1534
61	4826809	13.0000	5.5288	234	54756	12812904	15.2971	6.1622
00	4913000	13.0384	5.5397	235	55225	12977875	15.3297	6.1710
41	5000211	13.0767	5.5505	236	55696	13144256	15.3623	6.1797
84	5088448	13.1149	5.5613	237	56169	13312053	15.3948	6.1885
29	5177717	13.1529	5.5721	238	56644	13481272	15.4272	6.1972
76	5268024	13.1909	5.5828	239	57121	13651919	15.4596	6.2058
25	5359375	13.2288	5.5934	240	57600	13824000	15.4919	6.2145
76	5451776	13.2665	5.6041	241	58081	13997521	15.5242	6.2231
29	5545233	13.3041	5.6147	242	58564	14172488	15.5563	6.2317
84	5639752	13.3417	5.6252	243	59049	14348907	15.5885	6.2403
41	5735339	13.3791	5.6357	244	59536	14526784	15.6205	6.2488
00	5832000	13.4164	5.6462	245	60025	14706125	15.6525	6.2573
61	5929741	13.4536	5.6567	246	60516	14886936	15.6844	6.2658
24	6028568	13.4907	5.6671	247	61009	15069223	15.7162	6.2743
89	6128487	13.5277	5.6774	248	61504	15252992	15.7480	6.2828
56	6229504	13.5647	5.6877	249	62001	15438249	15.7797	6.2912
25	6331625	13.6015	5.6980	250	62500	15625000	15.8114	6.2996

[illegible]

[redacted]

Table No. 46D.

Square, Cube, Square Root and Cube Root of Each Whole Number From

381 to 510

INCLUSIVE.

No.	Square.	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	C. Rt.
381	145161	55306341	19.5192	7.2495	446	198916	88716536	21.1187	7.6403
382	145924	55742968	19.5448	7.2558	447	199809	89314623	21.1424	7.6460
383	146689	56181887	19.5704	7.2622	448	200704	89915392	21.1660	7.6517
384	147456	56623104	19.5959	7.2685	449	201601	90518849	21.1896	7.6574
385	148225	57066625	19.6214	7.2748	450	202500	91125000	21.2132	7.6631
386	148996	57512456	19.6469	7.2811	451	203401	91733851	21.2368	7.6688
387	149769	57960603	19.6723	7.2874	452	204304	92345408	21.2603	7.6744
388	150544	58411072	19.6977	7.2936	453	205209	92959677	21.2838	7.6801
389	151321	58863869	19.7231	7.2999	454	206116	93576664	21.3073	7.6857
390	152100	59319000	19.7484	7.3061	455	207025	94196375	21.3307	7.6914
391	152881	59776471	19.7737	7.3124	456	207936	94818816	21.3542	7.6970
392	153664	60236288	19.7990	7.3186	457	208849	95443993	21.3776	7.7026
393	154449	60698457	19.8242	7.3248	458	209764	96071912	21.4009	7.7082
394	155236	61162984	19.8494	7.3310	459	210681	96702579	21.4243	7.7138
395	156025	61629875	19.8746	7.3372	460	211600	97336000	21.4476	7.7194
396	156816	62099136	19.8997	7.3434	461	212521	97972181	21.4709	7.7250
397	157609	62570773	19.9249	7.3496	462	213444	98611128	21.4942	7.7306
398	158404	63044792	19.9499	7.3558	463	214369	99252847	21.5174	7.7362
399	159201	63521199	19.9750	7.3619	464	215296	99897344	21.5407	7.7418
400	160000	64000000	20.0000	7.3681	465	216225	100544625	21.5639	7.7473
401	160801	64481201	20.0250	7.3742	466	217156	101194696	21.5870	7.7529
402	161604	64964808	20.0499	7.3803	467	218089	101847563	21.6102	7.7584
403	162409	65450827	20.0749	7.3864	468	219024	102503232	21.6333	7.7639
404	163216	65939264	20.0998	7.3925	469	219961	103161709	21.6564	7.7695
405	164025	66430125	20.1246	7.3986	470	220900	103823000	21.6795	7.7750
406	164836	66923416	20.1494	7.4047	471	221841	104487111	21.7025	7.7805
407	165649	67419143	20.1742	7.4108	472	222784	105154048	21.7256	7.7860
408	166464	67917312	20.1990	7.4169	473	223729	105823817	21.7486	7.7915
409	167281	68417929	20.2237	7.4229	474	224676	106496424	21.7715	7.7970
410	168100	68921000	20.2485	7.4290	475	225625	107171875	21.7945	7.8025
411	168921	69426531	20.2731	7.4350	476	226576	107850176	21.8174	7.8079
412	169744	69934528	20.2978	7.4410	477	227529	108531333	21.8403	7.8134
413	170569	70444997	20.3224	7.4470	478	228484	109215352	21.8632	7.8188
414	171396	70957944	20.3470	7.4530	479	229441	109902239	21.8861	7.8243
415	172225	71473375	20.3715	7.4590	480	230400	110592000	21.9089	7.8297
416	173056	71991296	20.3961	7.4650	481	231361	111284641	21.9317	7.8352
417	173889	72511713	20.4206	7.4710	482	232324	111980168	21.9545	7.8406
418	174724	73034632	20.4450	7.4770	483	233289	112678587	21.9773	7.8460
419	175561	73560059	20.4695	7.4829	484	234256	113379904	22.0000	7.8514
420	176400	74088000	20.4939	7.4889	485	235225	114084125	22.0127	7.8568
421	177241	74618461	20.5183	7.4948	486	236196	114791256	22.0454	7.8622
422	178084	75151448	20.5426	7.5007	487	237169	115501303	22.0681	7.8676
423	178929	75686967	20.5670	7.5067	488	238144	116214272	22.0907	7.8730
424	179776	76225024	20.5913	7.5126	489	239121	116930169	22.1133	7.8784
425	180625	76765625	20.6155	7.5185	490	240100	117649000	22.1359	7.8837
426	181476	77308776	20.6398	7.5244	491	241081	118370771	22.1585	7.8891
427	182329	77854483	20.6640	7.5302	492	242064	119095488	22.1811	7.8944
428	183184	78402752	20.6882	7.5361	493	243049	119823157	22.2036	7.8998
429	184041	78953589	20.7123	7.5420	494	244036	120553784	22.2261	7.9051
430	184900	79507000	20.7364	7.5478	495	245025	121287375	22.2486	7.9105
431	185761	80062991	20.7605	7.5537	496	246016	122023936	22.2711	7.9158
432	186624	80621568	20.7846	7.5595	497	247009	122763473	22.2935	7.9211
433	187489	81182737	20.8087	7.5654	498	248004	123505992	22.3159	7.9264
434	188356	81746504	20.8327	7.5712	499	249001	124251499	22.3383	7.9317
435	189225	82312875	20.8567	7.5770	500	250000	125000000	22.3607	7.9370
436	190096	82881856	20.8806	7.5828	501	251001	125751501	22.3830	7.9423
437	190969	83453453	20.9045	7.5886	502	252004	126506008	22.4054	7.9476
438	191844	84027672	20.9284	7.5944	503	253009	127263527	22.4277	7.9528
439	192721	84604519	20.9523	7.6001	504	254016	128024064	22.4499	7.9581
440	193600	85184000	20.9762	7.6059	505	255025	128787625	22.4722	7.9634
441	194481	85766121	21.0000	7.6117	506	256036	129554216	22.4944	7.9686
442	195364	86350888	21.0238	7.6174	507	257049	130323843	22.5117	7.9739
443	196249	86938307	21.0476	7.6232	508	258064	131096512	22.5389	7.9791
444	197136	87528384	21.0713	7.6289	509	259081	131872229	22.5610	7.9843
445	198025	88121125	21.0950	7.6346	510	260100	132651000	22.5832	7.9896

Table No. 46E.

Square, Cube, Square Root and Cube Root of Each Whole Number From

511 to 640

INCLUSIVE.

No.	Square.	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	C. Rt.
511	261121	133432831	22.6053	7.9948	576	331776	191102976	24.0000	8.3203
512	262144	134217728	22.6274	8.0000	577	332929	192100033	24.0208	8.3251
513	263169	135005697	22.6495	8.0052	578	334084	193100552	24.0416	8.3300
514	264196	135796744	22.6716	8.0104	579	335241	194104539	24.0624	8.3348
515	265225	136590875	22.6936	8.0156	580	336400	195112000	24.0832	8.3396
516	266256	137388096	22.7156	8.0208	581	337561	196122941	24.1039	8.3443
517	267289	138188413	22.7376	8.0260	582	338724	197137368	24.1247	8.3491
518	268324	138991832	22.7596	8.0311	583	339889	198155287	24.1454	8.3539
519	269361	139798359	22.7816	8.0363	584	341056	199176704	24.1661	8.3587
520	270400	140608000	22.8035	8.0415	585	342225	200201625	24.1868	8.3634
521	271441	141420761	22.8254	8.0466	586	343396	201230056	24.2074	8.3682
522	272484	142236648	22.8473	8.0517	587	344569	202262003	24.2281	8.3730
523	273529	143055667	22.8692	8.0569	588	345744	203297472	24.2487	8.3777
524	274576	143877824	22.8910	8.0620	589	346921	204336469	24.2693	8.3825
525	275625	144703125	22.9129	8.0671	590	348100	205379000	24.2899	8.3872
526	276676	145531576	22.9347	8.0723	591	349281	206425071	24.3105	8.3919
527	277729	146363183	22.9565	8.0774	592	350464	207474688	24.3311	8.3967
528	278784	147197952	22.9783	8.0825	593	351649	208527857	24.3516	8.4014
529	279841	148035889	23.0000	8.0876	594	352836	209584584	24.3721	8.4061
530	280900	148877000	23.0217	8.0927	595	354025	210644875	24.3926	8.4108
531	281961	149721291	23.0434	8.0978	596	355216	211708736	24.4131	8.4155
532	283024	150568768	23.0651	8.1028	597	356409	212776173	24.4336	8.4202
533	284089	151419437	23.0868	8.1079	598	357604	213847192	24.4540	8.4249
534	285156	152273304	23.1084	8.1130	599	358801	214921799	24.4745	8.4296
535	286225	153130375	23.1301	8.1180	600	360000	216000000	24.4949	8.4343
536	287296	153990656	23.1517	8.1231	601	361201	217081801	24.5153	8.4390
537	288369	154854153	23.1733	8.1281	602	362404	218167208	24.5357	8.4437
538	289444	155720872	23.1948	8.1332	603	363609	219256227	24.5561	8.4484
539	290521	156590819	23.2164	8.1382	604	364816	220348864	24.5764	8.4530
540	291600	157464000	23.2379	8.1433	605	366025	221445125	24.5967	8.4577
541	292681	158340421	23.2594	8.1483	606	367236	222545016	24.6171	8.4623
542	293764	159220088	23.2809	8.1533	607	368449	223648543	24.6374	8.4670
543	294849	160103007	23.3024	8.1583	608	369664	224755712	24.6577	8.4716
544	295936	160989184	23.3238	8.1633	609	370881	225866529	24.6779	8.4763
545	297025	161878625	23.3452	8.1683	610	372100	226981000	24.6982	8.4809
546	298116	162771336	23.3666	8.1733	611	373321	228099131	24.7184	8.4856
547	299209	163667323	23.3880	8.1783	612	374544	229220928	24.7386	8.4902
548	300304	164566592	23.4094	8.1833	613	375769	230346397	24.7588	8.4948
549	301401	165469149	23.4307	8.1882	614	376996	231475544	24.7790	8.4994
550	302500	166375000	23.4521	8.1932	615	378225	232608375	24.7992	8.5040
551	303601	167284151	23.4734	8.1982	616	379456	233744896	24.8193	8.5086
552	304704	168196608	23.4947	8.2031	617	380689	234885113	24.8395	8.5132
553	305809	169112377	23.5160	8.2081	618	381924	236029032	24.8596	8.5178
554	306916	170031464	23.5372	8.2130	619	383161	237176659	24.8797	8.5224
555	308025	170953875	23.5584	8.2180	620	384400	238328000	24.8998	8.5270
556	309136	171879616	23.5797	8.2229	621	385641	239483061	24.9199	8.5316
557	310249	172808693	23.6008	8.2278	622	386884	240641848	24.9399	8.5362
558	311364	173741112	23.6220	8.2327	623	388129	241804367	24.9600	8.5408
559	312481	174676879	23.6432	8.2377	624	389376	242970624	24.9800	8.5453
560	313600	175616000	23.6643	8.2426	625	390625	244140625	25.0000	8.5499
561	314721	176558481	23.6854	8.2475	626	391876	245314376	25.0200	8.5544
562	315844	177504328	23.7065	8.2524	627	393129	246491883	25.0400	8.5590
563	316969	178453547	23.7276	8.2573	628	394384	247673152	25.0599	8.5635
564	318096	179406144	23.7487	8.2621	629	395641	248858189	25.0799	8.5681
565	319225	180362125	23.7697	8.2670	630	396900	250047000	25.0998	8.5726
566	320356	181321496	23.7908	8.2719	631	398161	251239591	25.1197	8.5772
567	321489	182284263	23.8118	8.2768	632	399424	252435968	25.1396	8.5817
568	322624	183250432	23.8328	8.2816	633	400689	253636137	25.1595	8.5862
569	323761	184220009	23.8537	8.2865	634	401956	254840104	25.1794	8.5907
570	324900	185193000	23.8747	8.2913	635	403225	256047875	25.1992	8.5952
571	326041	186169411	23.8956	8.2962	636	404496	257259456	25.2190	8.5997
572	327184	187149248	23.9165	8.3010	637	405769	258474853	25.2389	8.6043
573	328329	188132517	23.9374	8.3059	638	407044	259694072	25.2587	8.6088
574	329476	189119224	23.9583	8.3107	639	408321	260917119	25.2784	8.6132
575	330625	190109375	23.9792	8.3155	640	409600	262144000	25.2982	8.6177

Table No. 46F.

Square, Cube, Square Root and Cube Root of Each Whole Number From

641 to 770

INCLUSIVE.

No.	Square.	Cube.	Sq. Rt.	C. Rt.	No.	Square.	Cube.	Sq. Rt.	R. Ct.
641	410881	263374721	25.3180	8.6222	706	498436	351895816	26.5707	8.9043
642	412164	264609288	25.3377	8.6267	707	499849	353393243	26.5895	8.9085
643	413449	265847707	25.3574	8.6312	708	501264	354894912	26.6083	8.9127
644	414736	267089984	25.3772	8.6357	709	502681	356400829	26.6271	8.9169
645	416025	268336125	25.3969	8.6401	710	504100	357911000	26.6458	8.9211
646	417316	269586136	25.4165	8.6446	711	505521	359425431	26.6646	8.9253
647	418609	270840023	25.4362	8.6490	712	506944	360944128	26.6833	8.9295
648	419904	272097792	25.4558	8.6535	713	508369	362467097	26.7021	8.9337
649	421201	273359449	25.4755	8.6579	714	509796	363994344	26.7208	8.9378
650	422500	274625000	25.4951	8.6624	715	511225	365525875	26.7395	8.9420
651	423801	275894451	25.5147	8.6668	716	512656	367061696	26.7582	8.9462
652	425104	277167808	25.5343	8.6713	717	514089	368601813	26.7769	8.9503
653	426409	278445077	25.5539	8.6757	718	515524	370146232	26.7955	8.9545
654	427716	279726264	25.5734	8.6801	719	516961	371694959	26.8142	8.9587
655	429025	281011375	25.5930	8.6845	720	518400	373248000	26.8328	8.9628
656	430336	282300416	25.6125	8.6890	721	519841	374805361	26.8514	8.9670
657	431649	283593393	25.6320	8.6934	722	521284	376367048	26.8701	8.9711
658	432964	284890312	25.6515	8.6978	723	522729	377933067	26.8887	8.9752
659	434281	286191179	25.6710	8.7022	724	524176	379503424	26.9072	8.9794
660	435600	287496000	25.6905	8.7066	725	525625	381078125	26.9258	8.9835
661	436921	288804781	25.7099	8.7110	726	527076	382657176	26.9444	8.9876
662	438244	290117528	25.7294	8.7154	727	528529	384240583	26.9629	8.9918
663	439569	291434247	25.7488	8.7198	728	529984	385828352	26.9815	8.9959
664	440896	292754944	25.7682	8.7241	729	531441	387420489	27.0000	9.0000
665	442225	294079625	25.7876	8.7285	730	532900	389017000	27.0185	9.0041
666	443556	295408296	25.8070	8.7329	731	534361	390617891	27.0370	9.0082
667	444889	296740963	25.8263	8.7373	732	535824	392223168	27.0555	9.0123
668	446224	298077632	25.8457	8.7416	733	537289	393832837	27.0740	9.0164
669	447561	299418309	25.8650	8.7460	734	538756	395446904	27.0924	9.0205
670	448900	300763000	25.8844	8.7503	735	540225	397065375	27.1109	9.0246
671	450241	302111711	25.9037	8.7547	736	541696	398688256	27.1293	9.0287
672	451584	303464448	25.9230	8.7590	737	543169	400315553	27.1477	9.0328
673	452929	304821217	25.9422	8.7634	738	544644	401947272	27.1662	9.0369
674	454276	306182024	25.9615	8.7677	739	546121	403583419	27.1846	9.0410
675	455625	307546875	25.9808	8.7721	740	547600	405224000	27.2029	9.0450
676	456976	308915776	26.0000	8.7764	741	549081	406869021	27.2213	9.0491
677	458329	310288733	26.0192	8.7807	742	550564	408518488	27.2397	9.0532
678	459684	311665752	26.0384	8.7850	743	552049	410172407	27.2580	9.0572
679	461041	313046839	26.0576	8.7893	744	553536	411830784	27.2764	9.0613
680	462400	314432000	26.0768	8.7937	745	555025	413493625	27.2947	9.0654
681	463761	315821241	26.0960	8.7980	746	556516	415160936	27.3130	9.0694
682	465124	317214568	26.1151	8.8023	747	558009	416832723	27.3313	9.0735
683	466489	318611987	26.1343	8.8066	748	559504	418508992	27.3496	9.0775
684	467856	320013504	26.1534	8.8109	749	561001	420189749	27.3679	9.0816
685	469225	321419125	26.1725	8.8152	750	562500	421875000	27.3861	9.0856
686	470596	322828856	25.1916	8.8194	751	564001	423564751	27.4044	9.0896
687	471969	324242703	26.2107	8.8237	752	565504	425259008	27.4226	9.0937
688	473344	325660672	26.2298	8.8280	753	567009	426957777	27.4408	9.0977
689	474721	327082769	26.2488	8.8323	754	568516	428661064	27.4591	9.1017
690	476100	328509000	26.2679	8.8366	755	570025	430368875	27.4773	9.1057
691	477481	329939371	26.2869	8.8408	756	571536	432081216	27.4955	9.1098
692	478864	331373888	26.3059	8.8451	757	573049	433798093	27.5136	9.1138
693	480249	332812557	26.3249	8.8493	758	574564	435519512	27.5318	9.1178
694	481636	334255384	26.3439	8.8536	759	576081	437245479	27.5500	9.1218
695	483025	335702375	26.3629	8.8578	760	577600	438976000	27.5681	9.1258
696	484416	337153536	26.3818	8.8621	761	579121	440711081	27.5862	9.1298
697	485809	338608873	26.4008	8.8663	762	580644	442450728	27.6043	9.1338
698	487204	340068392	26.4197	8.8706	763	582169	444194947	27.6225	9.1378
699	488601	341532099	26.4386	8.8748	764	583696	445943744	27.6405	9.1418
700	490000	343000000	26.4575	8.8790	765	585225	447697125	27.6586	9.1458
701	491401	344472101	26.4764	8.8833	766	586756	449455096	27.6767	9.1498
702	492804	345948408	26.4953	8.8875	767	588289	451217663	27.6948	9.1537
703	494209	347428927	26.5141	8.8917	768	589824	452984832	27.7128	9.1577
704	495616	348913664	26.5330	8.8959	769	591361	454756609	27.7308	9.1617
705	497025	350402625	26.5518	8.9001	770	592900	456533000	27.7489	9.1657

Table No. 47.

Mantissa of Logarithms of Numbers From 0 to 10

(Common System—Base 10.)

No.	0	1	2	3	4	5	6	7	8	9	Pr
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424	
10	00000	00432	00860	01283	01703	02118	02530	02938	03342	03742	4
11	04139	04532	04921	05307	05690	06069	06445	06818	07188	07554	3
12	07918	08278	08635	08990	09342	09691	10037	10380	10721	11059	3
13	11394	11727	12057	12385	12710	13033	13353	13672	13987	14301	3
14	14613	14921	15228	15533	15836	16136	16435	16731	17026	17318	3
15	17609	17897	18184	18469	18752	19033	19312	19590	19865	20139	2
16	20412	20682	20951	21218	21484	21748	22010	22271	22530	22788	2
17	23045	23299	23552	23804	24054	24303	24551	24797	25042	25285	2
18	25527	25767	26007	26245	26481	26717	26951	27184	27415	27646	2
19	27875	28103	28330	28555	28780	29003	29225	29446	29666	29885	2
20	30103	30319	30535	30749	30963	31175	31386	31597	31806	32014	2
21	32222	32428	32633	32838	33041	33243	33445	33646	33845	34044	2
22	34242	34439	34635	34830	35024	35218	35410	35602	35793	35983	1
23	36173	36361	36548	36736	36921	37106	37291	37474	37657	37839	1
24	38021	38201	38381	38560	38739	38916	39093	39269	39446	39619	1
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	1
26	41497	41664	41830	41996	42160	42324	42488	42651	42813	42975	1
27	43136	43296	43456	43616	43775	43933	44090	44248	44404	44560	1
28	44716	44870	45024	45178	45331	45484	45636	45788	45939	46089	1
29	46240	46389	46538	46686	46834	46982	47129	47275	47421	47567	1
30	47712	47856	48000	48144	48287	48430	48572	48713	48855	48995	1
31	49136	49276	49415	49554	49693	49831	49968	50105	50242	50379	1
32	50515	50650	50785	50920	51054	51188	51321	51454	51587	51719	1
33	51851	51982	52113	52244	52374	52504	52633	52763	52891	53020	1
34	53148	53275	53403	53529	53655	53781	53907	54033	54157	54282	1
35	54407	54530	54654	54777	54900	55022	55145	55266	55388	55509	1
36	55630	55750	55870	55990	56110	56229	56348	56466	56584	56702	1
37	56820	56937	57054	57170	57287	57403	57518	57634	57749	57863	1
38	57978	58092	58206	58319	58433	58546	58658	58771	58883	58995	1
39	59106	59217	59328	59439	59549	59659	59769	59879	59988	60097	1
40	60206	60314	60423	60530	60638	60745	60852	60959	61066	61172	1
41	61278	61384	61490	61595	61700	61804	61909	62013	62118	62221	1
42	62325	62428	62531	62634	62736	62838	62941	63042	63144	63245	1
43	63347	63447	63548	63649	63749	63848	63948	64048	64147	64246	
44	64345	64444	64542	64640	64738	64836	64933	65030	65127	65224	
45	65321	65417	65513	65609	65705	65801	65896	65991	66086	66181	
46	66276	66370	66464	66558	66651	66745	66838	66931	67024	67117	
47	67210	67302	67394	67486	67577	67669	67760	67851	67942	68033	
48	68124	68214	68304	68394	68484	68574	68663	68752	68842	68930	
49	69020	69108	69196	69284	69372	69460	69548	69635	69722	69810	
50	69897	69983	70070	70156	70243	70329	70415	70500	70586	70671	
51	70757	70842	70927	71011	71096	71180	71265	71349	71433	71516	
52	71600	71683	71767	71850	71933	72016	72098	72181	72263	72345	
53	72428	72509	72591	72673	72754	72835	72916	72997	73078	73158	
54	73239	73319	73400	73480	73560	73640	73719	73798	73878	73957	
55	74036	74115	74194	74273	74351	74429	74507	74585	74663	74741	
56	74819	74896	74974	75051	75128	75205	75282	75358	75434	75511	
57	75587	75663	75739	75815	75891	75967	76042	76117	76192	76267	
58	76342	76417	76492	76566	76641	76715	76789	76863	76937	77011	
59	77085	77158	77232	77305	77378	77451	77524	77597	77670	77742	
60	77815	77887	77959	78031	78103	78175	78247	78318	78390	78461	
61	78533	78604	78675	78746	78816	78887	78958	79028	79098	79169	
62	79239	79309	79379	79448	79518	79588	79657	79726	79796	79865	
63	79934	80002	80071	80140	80208	80277	80345	80413	80482	80550	
64	80618	80685	80753	80821	80888	80956	81023	81090	81157	81224	
65	81291	81358	81424	81491	81557	81624	81690	81756	81822	81888	
66	81954	82020	82085	82151	82216	82282	82347	82412	82477	82542	
67	82607	82672	82736	82801	82866	82930	82994	83058	83123	83187	
68	83250	83314	83378	83442	83505	83569	83632	83695	83758	83821	
69	83884	83947	84010	84073	84136	84198	84260	84323	84385	84447	
	84509	84571	84633	84695	84757	84818	84880	84941	85003	85064	

*Each Mantissa above given is supposed to have
before it.

(Table continued on next page.)

Table No. 47. (Continued.)

MANTISSA OF LOGARITHMS OF NUMBERS FROM 0 TO 100.
(COMMON SYSTEM—BASE = 10.)

No.	0	1	2	3	4	5	6	7	8	9	Prop.
71	85125	85187	85248	85309	85369	85430	85491	85551	85612	85672	61
72	85733	85793	85853	85913	85973	86033	86093	86153	86213	86272	60
73	86332	86391	86451	86510	86569	86628	86687	86746	86805	86864	59
74	86923	86981	87040	87098	87157	87215	87273	87332	87390	87448	58
75	87506	87564	87621	87679	87737	87794	87852	87909	87966	88024	57
76	88081	88138	88195	88252	88309	88366	88422	88479	88536	88592	56
77	88649	88705	88761	88818	88874	88930	88986	89042	89098	89153	56
78	89209	89265	89320	89376	89431	89487	89542	89597	89652	89707	55
79	89762	89817	89872	89927	89982	90036	90091	90145	90200	90254	54
80	90309	90363	90417	90471	90525	90579	90633	90687	90741	90794	54
81	90848	90902	90955	91009	91062	91115	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91592	91645	91698	91750	91803	91855	53
83	91907	91960	92012	92064	92116	92168	92220	92272	92324	92376	52
84	92427	92479	92531	92582	92634	92685	92737	92788	92839	92890	51
85	92941	92993	93044	93095	93146	93196	93247	93298	93348	93399	51
86	93449	93500	93550	93601	93651	93701	93751	93802	93852	93902	50
87	93951	94001	94051	94101	94151	94200	94250	94300	94349	94398	49
88	94448	94497	94546	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94987	95036	95085	95133	95182	95230	95279	95327	95376	48
90	95424	95472	95520	95568	95616	95664	95712	95760	95808	95856	48
91	95904	95951	95999	96047	96094	96142	96189	96236	96284	96331	48
92	96378	96426	96473	96520	96567	96614	96661	96708	96754	96801	47
93	96848	96895	96941	96988	97034	97081	97127	97174	97220	97266	47
94	97312	97359	97406	97451	97497	97543	97589	97635	97680	97726	46
95	97772	97818	97863	97909	97954	98000	98046	98091	98136	98181	46
96	98227	98272	98317	98362	98407	98452	98497	98542	98587	98632	45
97	98677	98721	98766	98811	98855	98900	98946	98990	99033	99078	45
98	99122	99166	99211	99255	99299	99343	99387	99431	99475	99519	44
99	99563	99607	99651	99694	99738	99782	99825	99869	99913	99956	44

NOTE.—Each Mantissa above given is supposed to have a decimal point before it.

The characteristic of the Logarithm of a number is less by 1 than the number of digits preceeding the decimal point. The Logarithm of a number=characteristic + mantissa.

Thus characteristic of Log. 164.= 2.

Mantissa from table, .21484

Log. 164 = 2.21484

The Logarithm of a product = the sum of the logarithms of its factors.

The Logarithm of a quotient is found by subtracting the logarithm of the divisior from that of the dividend.

The Logarithm of any power of a number = the logarithm of the number × the exponent of the power.

The Logarithm of a root of a number = the logarithm of the number ÷ the index of the root.

The arithmetical complement = 0 — logarithm.

The arithmetical complement of a given logarithm is the logarithm of the reciprocal of the number corresponding to the given logarithm.

MENSURATION OF SURFACES.

ARRANGED ALPHABETICALLY.

CIRCLES.

The term "circle" as used in this work, unless otherwise mentioned, means the area within the bounding line called the circumference. In Analytic Geometry and other higher mathematics the term "circle" is generally applied not to the area, but the bounding line of the area.

Table No. 48.

Area of a circle, if not given in Tables 52 to 54B inclusive can be found as follows.

Area of a circle = radius squared × 3.1416.

" " " = diameter squared × .7854.

" " " = circumference squared × .07958.

" " " = ½ diameter × ½ circumference.

Area of circle : area any circumscribed straight sided figure :: circumference of circle : to periphery of circumscribed figure.

Any circle whose diameter is double that of another, contains four times the area of the other or the area of circles are to each other as the squares of their diameters.

Area of a circle = area of a triangle whose base = circumference, and height = the radius of the circle.

of circle to circumscribe a given square = .are × .7071 or = ½ the diagonal of the square. r × 1.3468 = side of an equilateral triangle of

r of circle equal in area to given ellipse $\sqrt{\text{uct of the long and short diameters of the}}$ se.

Table No. 49.

TO CIRCUMFERENCE, DIAMETER, AND RADIUS.

: not given in Tables No. 52 to 54B can be ollows:

$$\text{umference} = \begin{cases} \sqrt{\text{Area} \times 12.566} \text{ or} \\ \text{Diameter} \times 3.1416 \text{ or} \\ \text{Radius} \times 6.2832 \end{cases}$$

$$\text{neter} = \begin{cases} \text{Circumference} \div 3.1416 \text{ or} \\ \text{Circumference} \times .31831 \text{ or} \\ \sqrt{\text{Area} \div .7854} \text{ or} \\ \sqrt{\text{Area}} \times 1.1284 \end{cases}$$

$$\text{ius} = \begin{cases} \text{Circumference} \div 6.2832 \text{ or} \\ \text{Circumference} \times .1592 \text{ or} \\ \sqrt{\text{Area} \div 3.1416} \text{ or} \\ \sqrt{\text{Area}} \times .5642 \end{cases}$$

$$\text{ength of any arc} = \frac{\text{cir.} \times \text{no. degrees* in arc.}}{360}$$

= diameter of the circle of which the arc is a part × number of degrees* in arc × .0087266.

= No. of degrees × .017453292 × radius.

= No. of minutes × .00029088 × radius.

= No. of sec'nds × .000004848 × radius.

arc of 1°, radius 100′ = 1.74533 ft.

$\pi = 3.14159265$	$\frac{1}{\pi} = .31831$
og. $\pi = .4971499$	$\frac{1}{\pi^2} = .101321$
$\sqrt{\pi} = 1.772454$	$\frac{1}{\sqrt{\pi}} = .56419$
$\pi^2 = 9.8696044$	

and *seconds, if any*, must be reduced to decimal of a *table No. 50.*

Table No. 50.

Minutes and Seconds in Decimals of a Degree.

Min.	Deg.	Min.	Deg.	Min.	Deg.	Sec.	Deg.	Sec.	Deg.	Sec.	Deg.
1	.016666	21	.350000	41	.683333	1	.000278	21	.005833	41	[illegible]
2	.033333	22	.366666	42	.700000	2	.000556	22	.006111	42	[illegible]
3	.050000	23	.383333	43	.716666	3	.000833	23	.006389	43	[illegible]
4	.066666	24	.400000	44	.733333	4	.001111	24	.006667	44	[illegible]
5	.083333	25	.416666	45	.750000	5	.001389	25	.006944	45	[illegible]
6	.100000	26	.433333	46	.766666	6	.001667	26	.007222	46	[illegible]
7	.116666	27	.450000	47	.783333	7	.001944	27	.007500	47	[illegible]
8	.133333	28	.466666	48	.800000	8	.002222	28	.007778	48	[illegible]
9	.150000	29	.483333	49	.816666	9	.002500	29	.008056	49	[illegible]
10	.166666	30	.500000	50	.833333	10	.002778	30	.008333	50	[illegible]
11	.183333	31	.516666	51	.850000	11	.003056	31	.008611	51	[illegible]
12	.200000	32	.533333	52	.866666	12	.003333	32	.008889	52	[illegible]
13	.216666	33	.550000	53	.883333	13	.003611	33	.009167	53	[illegible]
14	.233333	34	.566666	54	.900000	14	.003889	34	.009444	54	[illegible]
15	.250000	35	.583333	55	.916666	15	.004167	35	.009722	55	[illegible]
16	.266666	36	.600000	56	.933333	16	.004444	36	.010000	56	[illegible]
17	.283333	37	.616666	57	.950000	17	.004722	37	.010278	57	[illegible]
18	.300000	38	.633333	58	.966666	18	.005000	38	.010556	58	[illegible]
19	.316666	39	.650000	59	.983333	19	.005278	39	.010833	59	[illegible]
20	.333333	40	.666666	60	1.000000	20	.005556	40	.011111	60	[illegible]

Circles.—Parts of.

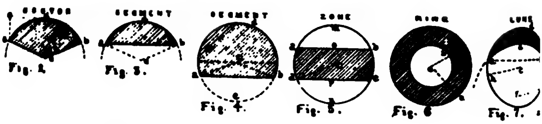


Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7.

Sector. Fig. 2.

Area length of arc a d b × ½ radius a c.

$$\text{radius}^2 \times 3.1416 \times \frac{\text{number of degrees in ar}}{360}$$

For length or arc, separately, see page 51.

Segment. Fig. 3, When it is less than a semi-circ

[redacted]

Cube.

Area of surface = length squared $\times$ 6.

Cycloid.

Area = area of the generating circle $\times$ 3,

Cylinder or Prism.

Area of surface. exclusive of top and base = circumference $\times$ height.

Ellipse.

Circumference of an ellipse = 3.1416 $\times$ square root of $\frac{1}{2}$ of the sum of the long and short diameters.

Area = long diameter $\times$ short diameter $\times$ .7854

Ellipsoid.

Area surface = 2.22 $\times$ short diameter $\times$ square root of the sum of the long and short diameters.

Frustrum of Cone or Pyramid.

Area surface, exclusive of top and base = sum of circumference of large and small ends $\times$ $\frac{1}{2}$ of slant height.

Irregular Surface.

When the base is a straight line, and the irregular bounding line of top is connected to base by two parallel ends at right angles to base.

Rule*.—Divide area into any number of equal width parallel strips, find center height of each:—then,

Area of irregular surface = width of a strip $\times$ sum of all the center heights.

The above rule is sufficiently accurate for most purposes in practice. Francke's or Poncelet's rule should be used when extreme accuracy is desired but are not here inserted, as they involve to much calculation to give a quick answer. Simpson's rule is more complicated, and not generally as accurate as Francke's or Poncelet's.

Parabola.

Area = base $\times$ $\frac{2}{3}$ height.

= $\frac{2}{3}$ area of circumscribing rectangle.

Parallelograms.

A Parallelogram is any figure bounded by four traight sides, the opposite ones of which are parallel. They are the Square, Rectangle, Rhombus and Rhomboid. The area of either is equal to one side $\times$ perpendicular distance between it and the opposite side r base $\times$ perpendicular height.

*This rule is sufficiently accurate in practice for irregular gure with both top and base an irregular line joining each other t two points or by two parallel ends.

... solid measure.

... matter how many ... are equal and th... sides equal to th... sides, th... are irregula...

Table No. II.

				Perpendicular on which side.	Interior angle contained between two sides.	Angle at centre subtended.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Square.

Area = square of one side.

One side = square root of area.

One side = square root of $\frac{1}{2}$ the square of the diagonal = diagonal × .7071.

Side of a square equal to the diagonal of a given square contains double the area of the given square.

Side of a square that will equal the area of a circle = diameter of circle × .8862 or circumference × .2821.

The diagonal = square root of twice the square of one side = one side × 1.4142.

Trapezoid.

Is a figure with four straight sides, two only of which are parallel.

Area = $\frac{1}{2}$ the sum of the lengths of the parallel sides × perpendicular distance between them.

Trapezium.

Is a figure with four straight sides, no two of which are parallel. To find area, divide into triangles and find the area of each, and add together.

Triangle.

Area = base × $\frac{1}{2}$ perpendicular height.

Area = $\frac{1}{2}$ area of a parallelogram having an equal base and height.

Area, when the length of the three sides are given: Find half the sum of the three sides, and from it subtract each side separately. Find the continued product of the half sum and three remainders and extract its square root; the result is the area required or by logarithms. Find the half sum and the three remainders, then find the half sum of their logarithms. The number corresponding = area of △ required.

Area, when two sides and included angle are given, see figure 21.

RULE.—Add together the logarithms of the two sides and the logarithmic sine of their included angle; from this sum subtract 10; the remainder will be the logarithm of double the area of the triangle. Find, from the table, the number corresponding to this logarithm, and divide it by 2; the quotient will be the area of △ required or one-half (product of the length of the two given sides × sine of included angle) = area of △ required.

Table No. 52.

[illegible] Areas of Circles for Each Foot [illegible] of a Foot) in Diameter From

1" to 14' 11"

INCLUSIVE.

Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
Sq. ft.	Ft. In.	Feet.	Sq. ft.	Ft. In.	Feet.	Sq. ft.
[illegible]	5 0	[illegible]	[illegible]	10 0	31.41593	78.5398
[illegible]	1	[illegible]	[illegible]	1	31.67773	79.8540
[illegible]	2	[illegible]	[illegible]	2	31.93953	81.1796
[illegible]	3	[illegible]	[illegible]	3	32.20132	82.5165
[illegible]	4	[illegible]	[illegible]	4	32.46312	83.8647
[illegible]	5	[illegible]	[illegible]	5	32.72492	85.2242
[illegible]	6	[illegible]	[illegible]	6	32.98672	86.5950
[illegible]	7	[illegible]	[illegible]	7	33.24852	87.9771
[illegible]	8	[illegible]	[illegible]	8	33.51032	89.3706
[illegible]	9	[illegible]	[illegible]	9	33.77212	90.7754
[illegible]	10	[illegible]	[illegible]	10	34.03392	92.1915
[illegible]	11	[illegible]	[illegible]	11	34.29572	93.5989
[illegible]	6 0	[illegible]	[illegible]	11 0	34.55752	95.0332
[illegible]	1	[illegible]	[illegible]	1	34.81932	96.4783
[illegible]	2	[illegible]	[illegible]	2	35.08112	97.9347
[illegible]	3	[illegible]	[illegible]	3	35.34292	99.4024
[illegible]	4	[illegible]	[illegible]	4	35.60472	100.8815
[illegible]	5	[illegible]	[illegible]	5	35.86652	102.3719
[illegible]	6	[illegible]	[illegible]	6	36.12832	103.8736
[illegible]	7	[illegible]	[illegible]	7	36.39011	105.3866
[illegible]	8	[illegible]	[illegible]	8	36.65191	106.9110
[illegible]	9	[illegible]	[illegible]	9	36.91371	108.4467
[illegible]	10	[illegible]	[illegible]	10	37.17551	109.9937
[illegible]	11	[illegible]	[illegible]	11	37.43731	111.5520
[illegible]	7 0	[illegible]	[illegible]	12 0	37.69911	113.0973
[illegible]	1	[illegible]	[illegible]	1	37.96091	114.6736
[illegible]	2	[illegible]	[illegible]	2	38.22271	116.2607
[illegible]	3	[illegible]	[illegible]	3	38.48451	117.8584
[illegible]	4	[illegible]	[illegible]	4	38.74631	119.4678
[illegible]	5	[illegible]	[illegible]	5	39.00811	121.0877
[illegible]	6	[illegible]	[illegible]	6	39.26991	122.7185
[illegible]	7	[illegible]	[illegible]	7	39.53171	124.3592
[illegible]	8	[illegible]	[illegible]	8	39.79351	126.0128
[illegible]	9	[illegible]	[illegible]	9	40.05531	127.6760
[illegible]	10	[illegible]	[illegible]	10	40.31711	129.3507
[illegible]	11	[illegible]	[illegible]	11	40.57891	131.0360
[illegible]	8 0	[illegible]	[illegible]	13 0	40.84070	132.7323
[illegible]	1	[illegible]	[illegible]	1	41.10250	134.4391
[illegible]	2	[illegible]	[illegible]	2	41.36430	136.1575
[illegible]	3	[illegible]	[illegible]	3	41.62610	137.8865
[illegible]	4	[illegible]	[illegible]	4	41.88790	139.6263
[illegible]	5	[illegible]	[illegible]	5	42.14970	141.3771
[illegible]	6	[illegible]	[illegible]	6	42.41150	143.1398
[illegible]	7	[illegible]	[illegible]	7	42.67330	144.9114
[illegible]	8	27.22714	58.99213	8	42.93510	146.6949
[illegible]	9	27.48894	60.13205	9	43.19690	148.4896
[illegible]	10	27.75074	61.28287	10	43.45870	150.2947
[illegible]	11	28.01253	62.44461	11	43.72050	152.1109
56637	9 0	28.27433	63.61725	14 0	43.98230	153.9380
09042	1	28.53613	64.80080	1	44.24410	155.7761
.63538	2	28.79793	65.99526	2	44.50590	157.6250
.18025	3	29.05973	67.20063	3	44.76770	159.4849
.74893	4	29.32153	68.41691	4	45.02949	161.3557
.32072	5	29.58333	69.64409	5	45.29129	163.2374
.90431	6	29.84513	70.88218	6	45.55309	165.1300
.49882	7	30.10693	72.13119	7	45.81489	167.0335
.10423	8	30.36873	73.39110	8	46.07669	168.9479
.72065	9	30.63053	74.66191	9	46.33849	170.8732
.34777	10	30.89233	75.94364	10	46.60029	172.8094
.98591	11	31.15413	77.23627	11.	46.86209	174.7565

[illegible]ivalent area in any other square measure. [illegible]e or Foreign) see Tables 24 to 30 inclusive. [illegible]nce of circle of given area × .2821 = side [illegible] equivalent area.

Table No. 52A.

(ES AND AREAS OF CIRCLES FOR EACH FOOT (WELFTH OF A FOOT) IN DIAMETER FROM

15′ to 29′ 11″

INCLUSIVE.

Dia. Ft. In.	Circumf. Feet.	Area. Sq. ft.	Dia. Ft. In.	Circumf. Feet.	Area. Sq. ft.
20 0	62.83185	314.1593	25 0	78.53982	490.8739
1	63.09365	316.7827	1	78.80162	494.1518
2	63.35545	319.4171	2	79.06342	497.4407
3	63.61725	322.0623	3	79.32521	500.7404
4	63.87905	324.7185	4	79.58701	504.0511
5	64.14085	327.3856	5	79.84881	507.3727
6	64.40265	330.0636	6	80.11061	510.7052
7	64.66445	332.7525	7	80.37241	514.0486
8	64.92625	335.4523	8	80.63421	517.4029
9	65.18805	338.1630	9	80.89601	520.7681
10	65.44985	340.8846	10	81.15781	524.1442
11	65.71165	343.6172	11	81.41961	527.5312
21 0	65.97345	346.3606	26 0	81.68141	530.9292
1	66.23525	349.1149	1	81.94321	534.3380
2	66.49704	351.8802	2	82.20501	537.7578
3	66.75884	354.6564	3	82.46681	541.1884
4	67.02064	357.4434	4	82.72861	544.6300
5	67.28244	360.2414	5	82.99041	548.0825
6	67.54424	363.0503	6	83.25221	551.5459
7	67.80604	365.8701	7	83.51400	555.0202
8	68.06784	368.7008	8	83.77580	558.5054
9	68.32964	371.5424	9	84.03760	562.0015
10	68.59144	374.3949	10	84.29940	565.5085
11	68.85324	377.2584	11	84.56120	569.0264
22 0	69.11504	380.1327	27 0	84.82300	572.5553
1	69.37684	383.0180	1	85.08480	576.0950
2	69.63864	385.9141	2	85.34660	579.6457
3	69.90044	388.8212	3	85.60840	583.2072
4	70.16224	391.7392	4	85.87020	586.7797
5	70.42404	394.6680	5	86.13200	590.3631
6	70.68583	397.6078	6	86.39380	593.9574
7	70.94763	400.5585	7	86.65560	597.5626
8	71.20943	403.5201	8	86.91740	601.1787
9	71.47123	406.4926	9	87.17920	604.8057
10	71.73303	409.4761	10	87.44100	608.4436
11	71.99483	412.4704	11	87.70279	612.0924
23 0	72.25663	415.4756	28 0	87.96459	615.7522
1	72.51843	418.4918	1	88.22639	619.4228
2	72.78023	421.5188	2	88.48819	623.1044
3	73.04203	424.5568	3	88.74999	626.7968
4	73.30383	427.6057	4	89.01179	630.5002
5	73.56563	430.6654	5	89.27359	634.2145
6	73.82743	433.7361	6	89.53539	637.9397
7	74.08923	436.8177	7	89.79719	641.6758
8	74.35103	439.9102	8	90.05899	645.4228
9	74.61283	443.0137	9	90.32079	649.1807
10	74.87462	446.1280	10	90.58259	652.9495
11	75.13642	449.2532	11	90.84439	656.7292
24 0	75.39822	452.3893	29 0	91.10619	660.5199
1	75.66002	455.5364	1	91.36799	664.3214
2	75.92182	458.6943	2	91.62979	668.1339
3	76.18362	461.8632	3	91.89159	671.9572
4	76.44542	465.0430	4	92.15338	675.7915
5	76.70722	468.2337	5	92.41518	679.6367
6	76.96902	471.4352	6	92.67698	683.4928
7	77.23082	474.6477	7	92.93878	687.3597
8	77.49262	477.8711	8	93.20058	691.2377
9	77.75442	481.1055	9	93.46238	695.1265
10	78.01622	484.3507	10	93.72418	699.0262
11	78.27802	487.6068	11	93.98598	702.9368

= contents of Round Tanks in cubic feet. (a)
= " " " " gallons.
= " " " " tons of water.
in any other measure multiply (a) by proper
able No. 32.

Table No. 52B.

[illegible] and Areas of Circles for Each Foot [illegible] Diameter [illegible] Diameter From

[illegible] to [illegible]

Inclusive.

Circumf.	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
Feet.	Sq. ft.	Ft. In.	Feet.	Sq. ft.	Ft. In.	Feet.	Sq. ft.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40 0	125.6637	1256.6371

equivalent area in any other square measure [illegible] see Tables [illegible] to [illegible] inclusive. [illegible] of circle of given area × .8862 = side of equivalent area.

Table No. 52C.

[illegible] Areas of Circles [illegible] of a Foot, [illegible]

45 to 59' 11"

Inclusive.

Dia.	Circumf.	Area.
Ft. In.	Feet.	Sq. ft.
50 0	157.0796	1963.4954
1	157.3414	[illegible]
2	157.6032	[illegible]
3	157.8650	1983.1794
4	158.1268	[illegible]
5	158.3886	[illegible]
6	158.6504	[illegible]
7	158.9122	[illegible]
8	159.1740	[illegible]
9	159.4358	[illegible]
10	159.6976	[illegible]
11	159.9594	[illegible]
51 0	160.2212	[illegible]
1	160.4830	[illegible]
2	160.7448	[illegible]
3	161.0066	[illegible]
4	161.2684	[illegible]
5	161.5302	[illegible]
6	161.7920	[illegible]
7	162.0538	[illegible]
8	162.3156	[illegible]
9	162.5774	[illegible]
10	162.8392	[illegible]
11	163.1010	[illegible]
52 0	163.3628	[illegible]
1	163.6246	[illegible]
2	163.8864	[illegible]
3	164.1482	[illegible]
4	164.4100	[illegible]
5	164.6718	[illegible]
6	164.9336	[illegible]
7	165.1954	[illegible]
8	165.4572	[illegible]
9	165.7190	[illegible]
10	165.9808	[illegible]
11	166.2426	[illegible]
53 0	166.5044	[illegible]
1	166.7662	[illegible]
[illegible]	[illegible]	[illegible]

Table No. 52C.

…AND AREAS OF CIRCLES FOR EACH FOOT …LFTH OF A FOOT) IN DIAMETER FROM 45′ to 59′ 11″ INCLUSIVE.

Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
Ft. In.	Feet.	Sq. ft.	Ft. In.	Feet.	Sq. ft.
50 0	157.0796	1963.4954	55 0	172.7876	2375.8294
1	157.3414	1970.0458	1	173.0494	2383.0344
2	157.6032	1976.6072	2	173.3112	2390.2502
3	157.8650	1983.1794	3	173.5730	2397.4770
4	158.1268	1989.7626	4	173.8348	2404.7146
5	158.3886	1996.3567	5	174.0966	2411.9632
6	158.6504	2002.9617	6	174.3584	2419.2227
7	158.9122	2009.5776	7	174.6202	2426.4931
8	159.1740	2016.2044	8	174.8820	2433.7744
9	159.4358	2022.8421	9	175.1438	2441.0666
10	159.6976	2029.4907	10	175.4056	2448.3697
11	159.9594	2036.1502	11	175.6674	2455.6837
51 0	160.2212	2042.8206	56 0	175.9292	2463.0086
1	160.4830	2049.5020	1	176.1910	2470.3445
2	160.7448	2056.1942	2	176.4528	2477.6912
3	161.0066	2062.8974	3	176.7146	2485.0489
4	161.2684	2069.6114	4	176.9764	2492.4174
5	161.5302	2076.3364	5	177.2382	2499.7969
6	161.7920	2083.0728	6	177.5000	2507.1873
7	162.0538	2089.8191	7	177.7618	2514.5886
8	162.3156	2096.5768	8	178.0236	2522.0008
9	162.5774	2103.3454	9	178.2854	2529.4239
10	162.8392	2110.1249	10	178.5472	2526.8579
11	163.1010	2116.9153	11	178.8090	2544.3028
52 0	163.3628	2123.7166	57 0	179.0708	2551.7586
1	163.6246	2130.5289	1	179.3326	2559.2254
2	163.8864	2137.3520	2	179.5944	2566.7030
3	164.1482	2144.1861	3	179.8562	2574.1916
4	164.4100	2151.0310	4	180.1180	2581.6910
5	164.6718	2157.8869	5	180.3798	2589.2014
6	164.9336	2164.7537	6	180.6416	2596.7227
7	165.1954	2171.6314	7	180.9034	2604.2549
8	165.4572	2178.5200	8	181.1652	2611.7980
9	165.7190	2185.4195	9	181.4270	2619.3520
10	165.9808	2192.3299	10	181.6888	2626.9169
11	166.2426	2199.2512	11	181.9506	2634.4927
53 0	166.5044	2206.1834	58 0	182.2124	2642.0794
1	166.7662	2213.1266	1	182.4742	2649.6771
2	167.0280	2220.0806	2	182.7360	2657.2856
3	167.2898	2227.0456	3	182.9978	2664.9051
4	167.5516	2234.0214	4	183.2596	2672.5354
5	167.8134	2241.0082	5	183.5214	2680.1767
6	168.0752	2248.0059	6	183.7832	2687.8289
7	168.3370	2255.0145	7	184.0450	2695.4920
8	168.5988	2262.0340	8	184.3068	2703.1659
9	168.8606	2269.0644	9	184.5686	2710.8508
10	169.1224	2276.1057	10	184.8304	2718.5467
11	169.3842	2283.1579	11	185.0922	2726.2534
54 0	169.6460	2290.2210	59 0	185.3540	2733.9710
1	169.9078	2297.2951	1	185.6158	2741.6995
2	170.1696	2304.3800	2	185.8776	2749.4390
3	170.4314	2311.4759	3	186.1394	2757.1893
4	170.6932	2318.5826	4	186.4012	2764.9506
5	170.9550	2325.7003	5	186.6630	2772.7228
6	171.2168	2332.8289	6	186.9248	2780.5058
7	171.4786	2339.9684	7	187.1866	2788.2998
8	171.7404	2347.1188	8	187.4484	2796.1047
9	172.0022	2354.2801	9	187.7102	2803.9205
10	172.2640	2361.4523	10	187.9720	2811.7472
11	172.5258	2368.6354	11	188.2338	2819.5849

…epth = contents of Round Tanks in cubic feet. (a)
…18 = " " " " " gallons.
…031 = " " " " " tons of water.
…ents in any other measure multiply (a) by proper
…in Table No. 39.

Feet	Inches	Circumference	Area
67	6	212.057	[illegible]
	7	212.319	[illegible]
	8	212.581	[illegible]
	9	212.8[illegible]	[illegible]
	10	213.1047	[illegible]
	11	213.3665	[illegible]
68	0	213.6283	[illegible]
	1	213.8901	[illegible]
	2	214.1519	[illegible]
	3	214.4137	[illegible]
	4	214.6755	[illegible]
	5	214.9373	[illegible]
	6	215.1991	[illegible]
	7	215.4609	[illegible]
	8	215.7227	[illegible]
	9	215.9845	[illegible]
	10	216.2463	[illegible]
	11	216.5081	[illegible]
69	0	216.7699	3739.[illegible]
	1	217.0317	3748.[illegible]
	2	217.2935	3757.[illegible]
	3	217.5553	3766.[illegible]
	4	217.8171	3775.4962
	5	218.0789	3784.5774
	6	218.3407	3793.6695
	7	218.6025	3802.7725
	8	218.8643	3811.8864
	9	219.1261	3821.0112
	10	219.3879	3830.1469
	11	219.6497	3839.2935

...equivalent area in any other square ... Foreign) see Tables 24 to 30 ... circle of given area × ...

Table No. 52E.

CIRCUMFERENCES AND AREAS OF CIRCLES FOR EACH FOOT AND INCH (TWELFTH OF A FOOT) IN DIAMETER FROM

75′ to 89′ 11″

INCLUSIVE.

Dia.	Circumf.	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
Ft.In.	Feet.	Sq. ft.	Ft.In.	Feet.	Sq. ft.	Ft.In.	Feet.	Sq. ft.
75 0	235.6194	4417.8647	80 0	251.3274	5026.5482	85 0	267.0354	5674.5017
1	235.8812	4427.6876	1	251.5892	5037.0257	1	267.2972	5685.6337
2	236.1430	4437.5214	2	251.8510	5047.5140	2	267.5590	5696.7765
3	236.4048	4447.3662	3	252.1128	5058.0133	3	267.8208	5707.9302
4	236.6666	4457.2218	4	252.3746	5068.5234	4	268.0826	5719.0949
5	236.9284	4467.0884	5	252.6364	5079.0445	5	268.3444	5730.2705
6	237.1902	4476.9659	6	252.8982	5089.5764	6	268.6062	5741.4569
7	237.4520	4486.8543	7	253.1600	5100.1193	7	268.8680	5752.6543
8	237.7138	4496.7536	8	253.4218	5110.6731	8	269.1298	5763.8626
9	237.9756	4506.6637	9	253.6836	5121.2378	9	269.3916	5775.0818
10	238.2374	4516.5849	10	253.9454	5131.8134	10	269.6534	5786.3119
11	238.4992	4526.5169	11	254.2072	5142.3999	11	269.9152	5797.5529
76 0	238.7610	4536.4598	81 0	254.4690	5152.9974	86 0	270.1770	5808.8048
1	239.0228	4546.4136	1	254.7308	5163.6057	1	270.4388	5820.0676
2	239.2846	4556.3784	2	254.9926	5174.2249	2	270.7006	5831.3414
3	239.5464	4566.3540	3	255.2544	5184.8551	3	270.9624	5842.6260
4	230.8082	4576.3406	4	255.5162	5195.4961	4	271.2242	5853.9216
5	240.0700	4586.3380	5	255.7780	5206.1481	5	271.4860	5865.2280
6	240.3318	4596.3464	6	256.0398	5216.8110	6	271.7478	5876.5454
7	240.5936	4606.3657	7	256.3016	5227.4847	7	272.0096	5887.8737
8	240.8554	4616.3959	8	256.5634	5238.1694	8	272.2714	5899.2129
9	241.1172	4626.4370	9	256.8252	5248.8650	9	272.5332	5910.5630
10	241.3790	4636.4890	10	257.0870	5259.5715	10	272.7950	5921.9240
11	241.6408	4646.5519	11	257.3488	5270.2889	11	273.0568	5933.2959
77 0	241.9026	4656.6257	82 0	257.6106	5281.0178	87 0	273.3186	5944.6787
1	242.1644	4666.7104	1	257.8724	5291.7565	1	273.5804	5956.0724
2	242.4262	4676.8061	2	258.1342	5302.5066	2	273.8422	5967.4771
3	242.6880	4686.9126	3	258.3960	5313.2677	3	274.1040	5978.8926
4	242.9498	4697.0391	4	258.6578	5324.0396	4	274.3658	5990.3191
5	243.2116	4707.1584	5	258.9196	5334.8225	5	274.6276	6001.7564
6	243.4734	4717.2977	6	259.1814	5345.6162	6	274.8894	6013.2047
7	243.7352	4727.4479	7	259.4432	5356.4209	7	275.1512	6024.6639
8	243.9970	4737.6090	8	259.7050	5367.2365	8	275.4130	6036.1340
9	244.2588	4747.7810	9	259.9668	5378.0630	9	275.6748	6047.6149
10	244.5206	4757.9639	10	260.2286	5388.9004	10	275.9366	6059.1068
11	244.7824	4768.1577	11	260.4904	5399.7487	11	276.1984	6070.6097
78 0	245.0442	4778.3624	83 0	260.7522	5410.6079	88 0	276.4602	6082.1234
1	245.3060	4788.5781	1	261.0140	5421.4781	1	276.7220	6093.6480
2	245.5678	4798.8046	2	261.2758	5432.3591	2	276.9838	6105.1835
3	245.8296	4809.0420	3	261.5376	5443.2511	3	277.2456	6116.7300
4	246.0914	4819.2904	4	261.7994	5454.1539	4	277.5074	6128.2873
5	246.3532	4829.5497	5	262.0612	5465.0677	5	277.7692	6139.8556
6	246.6150	4839.8198	6	262.3230	5475.9923	6	278.0309	6151.4348
7	246.8768	4850.1009	7	262.5848	5486.9279	7	278.2927	6163.0248
8	247.1386	4860.3929	8	262.8466	5497.8744	8	278.5545	6174.6258
9	247.4004	4870.6958	9	263.1084	5508.8318	9	278.8163	6186.2377
10	247.6622	4881.0096	10	263.3702	5519.8001	10	279.0781	6197.8605
11	247.9240	4891.3343	11	263.6320	5530.7793	11	279.3399	6209.4942
79 0	248.1858	4901.6699	84 0	263.8938	5541.7694	89 0	279.6017	6221.1389
1	248.4476	4912.0165	1	264.1556	5552.7705	1	279.8635	6232.7944
2	248.7094	4922.3739	2	264.4174	5563.7824	2	280.1253	6244.4608
3	248.9712	4932.7423	3	264.6792	5574.8053	3	280.3871	6256.1382
4	249.2330	4943.1215	4	264.9410	5585.8390	4	280.6489	6267.8264
5	249.4948	4953.5117	5	265.2028	5596.8837	5	280.9107	6279.5256
6	249.7566	4963.9127	6	265.4646	5607.9392	6	281.1725	6291.2356
7	250.0184	4974.3247	7	265.7264	5619.0057	7	281.4343	6302.9566
8	250.2802	4984.7476	8	265.9882	5630.0831	8	281.6961	6314.6885
9	250.5420	4995.1814	9	266.2500	5641.1714	9	281.9579	6326.4313
10	250.8038	5005.6261	10	266.5118	5652.2706	10	282.2197	6338.1850
11	251.0656	5016.0817	11	266.7736	5663.3807	11	282.4815	6349.9496

Area × depth = contents of Round Tanks in cubic feet. (a)
(a) × 7.48 = " " " " " gallons.
(a) × .031 = " " " " " tons of water.
For contents in any other measure multiply (a) by proper equivalent in Table No. 33.

Table No. 52F.

Circumferences and Areas of Circles for Each and Inch (Twelfth of a Foot) in Diameter F

90 to 100

INCLUSIVE.

Dia.		Circumf.	Area.	Dia.		Circumf.	Area.	Dia.		Circumf.
Ft.	In.	Feet.	Sq. Ft.	Ft.	In.	Feet.	Sq. Ft.	Ft.	In.	Feet.
90	0	[illegible]	[illegible]	93	5	293.4771	6858.9184	96	9	303.9491
	1	[illegible]	[illegible]		6	293.7389	6866.1471		10	304.2109
	2	[illegible]	[illegible]		7	294.0007	6878.3917		11	304.4727
	3	[illegible]	[illegible]		8	294.2625	6890.6472	97	0	304.7345
	4	[illegible]	[illegible]		9	294.5243	6902.9135		1	304.9963
	5	[illegible]	[illegible]		10	294.7861	6915.1906		2	305.2581
	6	[illegible]	[illegible]		11	295.0479	6927.4791		3	305.5199
	7	[illegible]	[illegible]	94	0	295.3097	6939.7782		4	305.7517
	8	[illegible]	[illegible]		1	295.5715	6952.0882		5	306.0435
	9	[illegible]	[illegible]		2	295.8333	6964.4091		6	306.3053
	10	[illegible]	[illegible]		3	296.0951	6976.7410		7	306.5671
	11	[illegible]	[illegible]		4	296.3569	6989.0837		8	306.8289
91	0	[illegible]	[illegible]		5	296.6187	7001.4574		9	307.0907
	1	[illegible]	[illegible]		6	296.8805	7013.8019		10	307.3525
	2	[illegible]	[illegible]		7	297.1423	7026.1774		11	307.6143
	3	[illegible]	[illegible]		8	297.4041	7038.5638	98	0	307.8761
	4	[illegible]	[illegible]		9	297.6659	7050.9611		1	308.1379
	5	[illegible]	[illegible]		10	297.9277	7063.3693		2	308.3997
	6	[illegible]	[illegible]		11	298.1895	7075.7884		3	308.6615
	7	[illegible]	[illegible]	95	0	298.4513	7088.2184		4	308.9233
	8	[illegible]	[illegible]		1	298.7131	7100.6598		5	309.1851
	9	[illegible]	[illegible]		2	298.9749	7113.1112		6	309.4469
	10	[illegible]	[illegible]		3	299.2367	7125.5739		7	309.7087
	11	[illegible]	[illegible]		4	299.4985	7138.0476		8	309.9705
92	0	[illegible]	[illegible]		5	299.7603	7150.5821		9	310.2323
	1	[illegible]	[illegible]		6	300.0221	7163.0276		10	310.4941
	2	[illegible]	[illegible]		7	300.2839	7175.5840		11	310.7559
	3	[illegible]	[illegible]		8	300.5457	7188.0515	99	0	311.0177
	4	[illegible]	[illegible]		9	300.8075	7200.5794		1	311.2795
	5	[illegible]	[illegible]		10	301.0693	7213.1185		2	311.5413
	6	[illegible]	[illegible]		11	301.3311	7225.6686		3	311.8031
	7	[illegible]	[illegible]	96	0	301.5929	7238.2285		4	312.0649
	8	[illegible]	[illegible]		1	301.8547	7250.8013		5	312.3267
	9	[illegible]	[illegible]		2	302.1165	7263.3840		6	312.5885
	10	[illegible]	[illegible]		3	302.3783	7275.9777		7	312.8503
	11	[illegible]	[illegible]		4	302.6401	7288.5822		8	313.1121
93	0	[illegible]	[illegible]		5	302.9019	7301.1977		9	313.3739
	1	[illegible]	[illegible]		6	303.1637	7313.8240		10	313.6357
	2	[illegible]	[illegible]		7	303.4255	7326.4623		11	313.8975
	3	[illegible]	[illegible]		8	303.6873	7339.1095	100	0	314.1593
	4	[illegible]	[illegible]							

To find equivalent area in any other square me (U. S., Metric or Foreign) see Tables 24 to 30 incl

Circumference of a circle of given area × .2821 of a square of equivalent area.

In making rapid mental calculations, involvi square of numbers, such as diameter squared, squared, making comparison of round and square areas etc., it will be found convenient to rem that:—The difference of the squares of two conse whole numbers = the sum of the two numbers.

EXAMPLE. $89^2 = 7921$

$88^2 = 7744$

Sum $= 177 = 177$ the difference.

Table No. 53.

Circumferences and Areas of Circles for Each Foot and Tenth of a Foot in Diameter From

0'.1 to 18'.6

INCLUSIVE.

Dia.	Circumf.	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
0.1	.314159	.007854	6.3	19.79203	31.17245	12.5	39.26991	122.7185
.2	.628319	.031416	.4	20.10619	32.16991	.6	39.58407	124.6898
.3	.942478	.070686	.5	20.42035	33.18307	.7	39.89823	126.6769
.4	1.256637	.125664	.6	20.73451	34.21194	.8	40.21239	128.6796
.5	1.570796	.196350	.7	21.04867	35.25652	.9	40.52655	130.6981
.6	1.884956	.282743	.8	21.36283	36.31681	13.0	40.84070	132.7323
.7	2.199115	.384845	.9	21.67699	37.39281	.1	41.15486	134.7822
.8	2.513274	.502655	7.0	21.99115	38.48451	.2	41.46902	136.8478
.9	2.827433	.636173	.1	22.30531	39.59192	.3	41.78318	138.9291
1.0	3.141593	.785398	.2	22.61947	40.71504	.4	42.09734	141.0261
.1	3.455752	.950332	.3	22.93363	41.85387	.5	42.41150	143.1388
.2	3.769911	1.13097	.4	23.24779	43.00840	.6	42.72566	145.2672
.3	4.084070	1.32732	.5	23.56194	44.17865	.7	43.03982	147.4114
.4	4.398230	1.53938	.6	23.87610	45.36460	.8	43.35398	149.5712
.5	4.712389	1.76715	.7	24.19026	46.56626	.9	43.66814	151.7468
.6	5.026548	2.01062	.8	24.50442	47.78362	14.0	43.98230	153.9380
.7	5.340708	2.26980	.9	24.81858	49.01670	.1	44.29646	156.1450
.8	5.654867	2.54469	8.0	25.13274	50.26548	.2	44.61062	158.3677
.9	5.969026	2.83529	.1	25.44690	51.52997	.3	44.92477	160.6061
2.0	6.283185	3.14159	.2	25.76106	52.81017	.4	45.23893	162.8602
.1	6.597345	3.46361	.3	26.07522	54.10608	.5	45.55309	165.1300
.2	6.911504	3.80133	.4	26.38938	55.41769	.6	45.86725	167.4155
.3	7.225663	4.15476	.5	26.70354	56.74502	.7	46.18141	169.7167
.4	7.539822	4.52389	.6	27.01770	58.08805	.8	46.49557	172.0336
.5	7.853982	4.90874	.7	27.33186	59.44679	.9	46.80973	174.3662
.6	8.168141	5.30929	.8	27.64602	60.82123	15.0	47.12389	176.7146
.7	8.482300	5.72555	.9	27.96017	62.21139	.1	47.43805	179.0786
.8	8.796459	6.15752	9.0	28.27433	63.61725	.2	47.75221	181.4584
.9	9.110619	6.60520	.1	28.58849	65.03882	.3	48.06637	183.8539
3.0	9.424778	7.06858	.2	28.90265	66.47610	.4	48.38053	186.2650
.1	9.738937	7.54768	.3	29.21681	67.92909	.5	48.69469	188.6919
.2	10.05310	8.04248	.4	29.53097	69.39778	.6	49.00885	191.1345
.3	10.36726	8.55299	.5	29.84513	70.88218	.7	49.32300	193.5928
.4	10.68142	9.07920	.6	30.15929	72.38229	.8	49.63716	196.0668
.5	10.99557	9.62113	.7	30.47345	73.89811	.9	49.95132	198.5565
.6	11.30973	10.17876	.8	30.78761	75.42964	16.0	50.26548	201.0619
.7	11.62389	10.75210	.9	31.10177	76.97687	.1	50.57964	203.5831
.8	11.93805	11.34115	10.0	31.41593	78.53982	.2	50.89380	206.1199
.9	12.25221	11.94591	.1	31.73009	80.11847	.3	51.20796	208.6724
4.0	12.56637	12.56637	.2	32.04425	81.71282	.4	51.52212	211.2407
.1	12.88053	13.20254	.3	32.35840	83.32289	.5	51.83628	213.8246
.2	13.19469	13.85442	.4	32.67256	84.94867	.6	52.15044	216.4243
.3	13.50885	14.52201	.5	32.98672	86.59015	.7	52.46460	219.0397
.4	13.82301	15.20531	.6	33.30088	88.24734	.8	52.77876	221.6708
.5	14.13717	15.90431	.7	33.61504	89.92024	.9	53.09292	224.3176
.6	14.45133	16.61903	.8	33.92920	91.60884	17.0	53.40708	226.9801
.7	14.76549	17.34945	.9	34.24336	93.31316	.1	53.72128	229.6583
.8	15.07964	18.09557	11.0	34.55752	95.03318	.2	54.03539	232.3522
.9	15.39380	18.85741	.1	34.87168	96.76891	.3	54.34955	235.0618
5.0	15.70796	19.63495	.2	35.18584	98.52035	.4	54.66371	237.7871
.1	16.02212	20.42821	.3	35.50000	100.2875	.5	54.97787	240.5282
.2	16.33628	21.23717	.4	35.81416	102.0703	.6	55.29203	243.2849
.3	16.65044	22.06183	.5	36.12832	103.8689	.7	55.60619	246.0574
.4	16.96460	22.90221	.6	36.44247	105.6832	.8	55.92035	248.8456
.5	17.27876	23.75829	.7	36.75663	107.5132	.9	56.23451	251.6494
.6	17.59292	24.63009	.8	37.07079	109.3588	18.0	56.54867	254.4690
.7	17.90708	25.51759	.9	37.38495	111.2202	.1	56.86283	257.3043
.8	18.22124	26.42079	12.0	37.69911	113.0973	.2	57.17699	260.1553
.9	18.53540	27.33971	.1	38.01327	114.9901	.3	57.49115	263.0220
6.0	18.84956	28.27433	.2	38.32743	116.8987	.4	57.80530	265.9044
.1	19.16372	29.22467	.3	38.64159	118.8229	.5	58.11946	268.8025
.2	19.47787	30.19071	.4	38.95575	120.7628	.6	58.43362	271.7163

Area × depth = contents of Round Tanks in cubic feet. (a)
(a) × 7.48 = " " " " " gallons.
(a) × .031 = " " " " " tons of water.
For *contents in any* other measure multiply (a) by proper *equivalent in Table No. 33.*

[illegible]	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] equivalent area in any other square measure, [illegible] Metric or Foreign) see Tables [illegible] to [illegible] inclusive. [illegible] of a circle of given area × [illegible] = side [illegible] of a equivalent area.

Table No. 53C.

CIRCUMFERENCES AND AREAS OF CIRCLES FOR EACH FOOT AND TENTH OF A FOOT IN DIAMETER FROM

55.9 to 74.4

INCLUSIVE.

Dia.	Circumf.	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
55.9	175.6150	2454.2200	62.1	195.0929	3028.8779	68.3	214.5708	3663.7960
56.0	175.9292	2463.0086	.2	195.4071	3038.5796	.4	214.8849	3674.5324
.1	176.2433	2471.8130	.3	195.7212	3048.3580	.5	215.1991	3685.2845
.2	176.5575	2480.6330	.4	196.0354	3058.1520	.6	215.5133	3696.0523
.3	176.8717	2489.4687	.5	196.3496	3067.9616	.7	215.8274	3706.8359
.4	177.1858	2498.3201	.6	196.6637	3077.7869	.8	216.1416	3717.6351
.5	177.5000	2507.1873	.7	196.9779	3087.6279	.9	216.4557	3728.4501
.6	177.8141	2516.0701	.8	197.2920	3097.4847	69.0	216.7699	3739.2807
.7	178.1283	2524.9687	.9	197.6062	3107.3571	.1	217.0841	3750.1270
.8	178.4425	2533.8830	63.0	197.9203	3117.2453	.2	217.3982	3760.9891
.9	178.7566	2542.8129	.1	198.2345	3127.1492	.3	217.7124	3771.8668
57.0	179.0708	2551.7586	.2	198.5487	3137.0688	.4	218.0265	3782.7603
.1	179.3849	2560.7200	.3	198.8628	3147.0040	.5	218.3407	3793.6695
.2	179.6991	2569.6971	.4	199.1770	3156.9550	.6	218.6548	3804.5944
.3	180.0133	2578.6899	.5	199.4911	3166.9217	.7	218.9690	3815.5350
.4	180.3274	2587.6985	.6	199.8053	3176.9042	.8	219.2832	3826.4913
.5	180.6416	2596.7227	.7	200.1195	3186.9023	.9	219.5973	3837.4633
.6	180.9557	2605.7626	.8	200.4336	3196.9161	70.0	219.9115	3848.4510
.7	181.2699	2614.8183	.9	200.7478	3206.9456	.1	220.2256	3859.4544
.8	181.5841	2623.8896	64.0	201.0619	3216.9909	.2	220.5398	3870.4736
.9	181.8982	2632.9767	.1	201.3761	3227.0518	.3	220.8540	3881.5084
58.0	182.2124	2642.0794	.2	201.6902	3237.1285	.4	221.1681	3892.5590
.1	182.5265	2651.1979	.3	202.0044	3247.2209	.5	221.4823	3903.6252
.2	182.8407	2660.3321	.4	202.3186	3257.3289	.6	221.7964	3914.7072
.3	183.1549	2669.4820	.5	202.6327	3267.4527	.7	222.1106	3925.8049
.4	183.4690	2678.6476	.6	202.9469	3277.5922	.8	222.4248	3936.9182
.5	183.7832	2687.8289	.7	203.2610	3287.7474	.9	222.7389	3948.0473
.6	184.0973	2697.0259	.8	203.5752	3297.9183	71.0	223.0531	3959.1921
.7	184.4115	2706.2386	.9	203.8894	3308.1049	.1	223.3672	3970.3526
.8	184.7256	2715.4670	65.0	204.2035	3318.3072	.2	223.6814	3981.5289
.9	185.0398	2724.7112	.1	204.5177	3328.5253	.3	223.9956	3992.7208
59.0	185.3540	2733.9710	.2	204.8318	3338.7590	.4	224.3097	4003.9284
.1	185.6681	2743.2466	.3	205.1460	3349.0085	.5	224.6239	4015.1518
.2	185.9823	2752.5378	.4	205.4602	3359.2736	.6	224.9380	4026.3908
.3	186.2964	2761.8448	.5	205.7743	3369.5545	.7	225.2522	4037.6456
.4	186.6106	2771.1675	.6	206.0885	3379.8510	.8	225.5664	4048.9160
.5	186.9248	2780.5058	.7	206.4026	3390.1633	.9	225.8805	4060.2022
.6	[illegible]	[illegible]	.8	206.7168	3400.4913	72.0	226.1947	4071.5041
.7	[illegible]	[illegible]	.9	207.0310	3410.8350	.1	226.5088	4082.8217
.8	[illegible]	[illegible]	66.0	207.3451	3421.1944	.2	226.8230	4094.1550
.9	[illegible]	[illegible]	.1	207.6593	3431.5696	.3	227.1371	4105.5040
60.0	[illegible]	[illegible]	.2	207.9734	3441.9604	.4	227.4513	4116.8687
.1	[illegible]	[illegible]	.3	208.2876	3452.3669	.5	227.7655	4128.2491
.2	[illegible]	[illegible]	.4	208.6018	3462.7891	.6	228.0796	4139.6452
.3	[illegible]	[illegible]	.5	208.9159	3473.2270	.7	228.3938	4151.0571
.4	[illegible]	[illegible]	.6	209.2301	3483.6807	.8	228.7079	4162.4846
.5	[illegible]	[illegible]	.7	209.5442	3494.1500	.9	229.0221	4173.9279
.6	[illegible]	[illegible]	.8	209.8584	3504.6351	73.0	229.3363	4185.3868
.7	[illegible]	[illegible]	.9	210.1725	3515.1359	.1	229.6504	4196.8615
.8	[illegible]	[illegible]	67.0	210.4867	3525.6524	.2	229.9646	4208.3519
.9	[illegible]	[illegible]	.1	210.8009	3536.1845	.3	230.2787	4219.8579
61.0	[illegible]	[illegible]	.2	211.1150	3546.7324	.4	230.5929	4231.3797
.1	[illegible]	[illegible]	.3	211.4292	3557.2960	.5	230.9071	4242.9172
.2	[illegible]	[illegible]	.4	211.7433	3567.8754	.6	231.2212	4254.4704
.3	[illegible]	[illegible]	.5	212.0575	3578.4704	.7	231.5354	4266.0394
.4	[illegible]	[illegible]	.6	212.3717	3589.0811	.8	231.8495	4277.6240
.5	[illegible]	[illegible]	.7	212.6858	3599.7075	.9	232.1637	4289.2243
.6	[illegible]	[illegible]	.8	213.0000	3610.3497	74.0	232.4779	4300.8403
.7	[illegible]	[illegible]	.9	213.3141	3621.0075	.1	232.7920	4312.4721
.8	[illegible]	[illegible]	68.0	213.6283	3631.6811	.2	233.1062	4324.1195
.9	[illegible]	[illegible]	.1	213.9425	3642.3704	.3	233.4203	4335.7827
62.0	[illegible]	[illegible]	.2	214.2566	3653.0754	.4	233.7345	4347.4616

[illegible] that area in any other square measure, inclusive [illegible] Foreign see Tables 24 to 30 [illegible] × .2821 = side [illegible] of a circle of given area [illegible] equivalent area.

Table No. 53D.

FERENCES AND AREAS OF CIRCLES FOR EACH FOOT
AND TENTH OF A FOOT IN DIAMETER FROM

74.'5 to 93.'

INCLUSIVE.

rumf.	Area.	Dia.	Circumf.	Area.	Dia.	Circumf.	Area.
4.0487	4359.1562	80.7	253.5265	5114.8977	86.9	273.0044	5931.0206
4.3628	4370.8664	.8	253.8407	5127.5819	87.0	273.3186	5944.6787
4.6770	4382.5924	.9	254.1548	5140.2818	.1	273.6327	5958.3625
4.9911	4394.3341	81.0	254.4690	5152.9974	.2	273.9469	5972.0420
5.3053	4406.0916	.1	254.7832	5165.7287	.3	274.2610	5985.7472
5.6194	4417.8647	.2	255.0973	5178.4757	.4	274.5752	5999.4681
5.9336	4429.6535	.3	255.4115	5191.2384	.5	274.8894	6013.2047
.2478	4441.4580	.4	255.7256	5204.0168	.6	275.2035	6026.9570
.5619	4453.2783	.5	256.0398	5216.8110	.7	275.5177	6040.7250
.8761	4465.1142	.6	256.3540	5229.6208	.8	275.8318	6054.5088
1902	4476.9659	.7	256.6681	5242.4463	.9	276.1460	6068.3082
044	4488.8332	.8	256.9823	5255.2876	88.0	276.4602	6082.1234
186	4500.7163	.9	257.2964	5268.1446	.1	276.7743	6095.9542
327	4512.6151	82.0	257.6106	5281.0173	.2	277.0885	6109.8008
469	4524.5296	.1	257.9248	5293.9056	.3	277.4026	6123.6631
610	4536.4598	.2	258.2389	5306.8097	.4	277.7168	6137.5411
752	4548.4057	.3	258.5531	5319.7295	.5	278.0309	6151.4348
894	4560.3673	.4	258.8672	5332.6650	.6	278.3451	6165.3442
035	4572.3446	.5	259.1814	5345.6162	.7	278.6593	6179.2693
177	4584.3377	.6	259.4956	5358.5832	.8	278.9734	6193.2101
318	4596.3464	.7	259.8097	5371.5658	.9	279.2876	6207.1666
460	4608.3708	.8	260.1239	5384.5641	89.0	279.6017	6221.1389
602	4620.4110	.9	260.4380	5397.5782	.1	279.9159	6235.1268
743	4632.4669	83.0	260.7522	5410.6079	.2	280.2301	6249.1304
885	4644.5384	.1	261.0663	5423.6534	.3	280.5442	6263.1498
026	4656.6257	.2	261.3805	5436.7146	.4	280.8584	6277.1849
168	4668.7287	.3	261.6947	5449.7915	.5	281.1725	6291.2356
310	4680.8474	.4	262.0088	5462.8840	.6	281.4867	6305.3021
451	4692.9818	.5	262.3230	5475.9923	.7	281.8009	6319.3843
593	4705.1319	.6	262.6371	5489.1168	.8	282.1150	6333.4822
734	4717.2977	.7	262.9513	5502.2561	.9	282.4292	6347.5958
876	4729.4792	.8	263.2655	5515.4115	90.0	282.7433	6361.7251
017	4741.6765	.9	263.5796	5528.5826	.1	283.0575	6375.8701
159	4753.8894	84.0	263.8938	5541.7694	.2	283.3717	6390.0309
301	4766.1181	.1	264.2079	5554.9720	.3	283.6858	6404.2073
442	4778.3624	.2	264.5221	5568.1902	.4	284.0000	6418.3995
584	4790.6225	.3	264.8363	5581.4242	.5	284.3141	6432.6073
725	4802.8983	.4	265.1504	5594.6739	.6	284.6283	6446.8309
867	4815.1897	.5	265.4646	5607.9392	.7	284.9425	6461.0701
009	4827.4969	.6	265.7787	5621.2203	.8	285.2566	6475.3251
150	4839.8198	.7	266.0929	5634.5171	.9	285.5708	6489.5958
292	4852.1584	.8	266.4071	5647.8296	91.0	285.8849	6503.8822
433	4864.5128	.9	266.7212	5661.1578	.1	286.1991	6518.1843
575	4876.8828	85.0	267.0354	5674.5017	.2	286.5133	6532.5021
717	4889.2685	.1	267.3495	5687.8614	.3	286.8274	6546.8356
858	4901.6699	.2	267.6637	5701.2367	.4	287.1416	6561.1848
000	4914.0871	.3	267.9779	5714.6277	.5	287.4557	6575.5498
141	4926.5199	.4	268.2920	5728.0345	.6	287.7699	6589.9304
283	4938.9685	.5	268.6062	5741.4569	.7	288.0840	6604.3268
425	4951.4328	.6	268.9203	5754.8951	.8	288.3982	6618.7388
566	4963.9127	.7	269.2345	5768.3490	.9	288.7124	6633.1666
708	4976.4084	.8	269.5486	5781.8185	92.0	289.0265	6647.6101
849	4988.9198	.9	269.8628	5795.3038	.1	289.3407	6662.0692
991	5001.4469	86.0	270.1770	5808.8048	.2	289.6548	6676.5441
133	5013.9897	.1	270.4911	5822.3215	.3	289.9690	6691.0347
274	5026.5482	.2	270.8053	5835.8539	.4	290.2832	6705.5410
416	5039.1225	.3	271.1194	5849.4020	.5	290.5973	6720.0630
557	5051.7124	.4	271.4336	5862.9659	.6	290.9115	6734.6008
699	5064.3180	.5	271.7478	5876.5454	.7	291.2256	6749.1542
840	5076.9394	.6	272.0619	5890.1407	.8	291.5398	6763.7233
982	5089.5764	.7	272.3761	5903.7516	.9	291.8540	6778.3082
124	5102.2292	.8	272.6902	5917.3783	93.0	292.1681	6792.9087

× depth = contents of Round Tanks in cubic feet. (a)
× 7.48 = " " " " " gallons.
× .031 = " " " " " tons of water.
ntents in any other measure multiply (a) by proper
nt in Table No. 33.

Table No. [illegible]

CIRCUMFERENCES AND AREAS OF CIRCLES FOR EACH AND TENTH OF A FOOT IN DIAMETER FROM [illegible] TO [illegible]

(CONTINUED.)

Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

To find equivalent area in any other square me[illegible] (U. S., Metric or Foreign) see Tables 24 to 30 incl[illegible]

Circumference of a circle of given area. = .[illegible] of a square of equivalent area.

In making rapid mental calculations, involvi[illegible] square of numbers, such as diameter squared, [illegible] squared, making comparison of round and square [illegible] areas etc., it will be found convenient to rem[illegible] that.—The difference of the squares of two conse[illegible] numbers as 10 and 11, 10.5 and 11.5, etc., = the [illegible] the two numbers.

EXAMPLE. $89^2 = 7921$

$88^2 = 7744$

Sum = 177 = 177 the difference.

It frequently happens that the equivalent ci[illegible] area of an irregular figure, as shown by a drawi[illegible] desired.

Cut out same on tracing or other paper, an[illegible] UNIT CIRCULAR AREA from same paper to same sca[illegible]

Weigh both on analytical balances. The Are[illegible] directly proportional to the weights. The dia[illegible] corresponding to the resultant area, will be the dia[illegible] equivalent circular area desired.

Table No. 54.

CIRCUMFERENCES AND AREAS OF CIRCLES FOR EACH UNIT AND FREQUENTLY USED FRACTION OF A UNIT IN DIAMETER FROM

1-64 to 28 1-4

INCLUSIVE.

Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.
	.049087	.00019	3. ½	10.9956	9.6211	10⅛	31.8086	80.516	19¼	60.4757	291.04
	.098175	.00077	9-16	11.1919	9.9678	¼	32.2013	82.516	⅜	60.8684	294.83
	.147262	.00173	⅝	11.3883	10.321	⅜	32.5940	84.541	½	61.2611	298.65
	.196350	.00307	11-16	11.5846	10.680	½	32.9867	86.590	⅝	61.6538	302.49
	.294524	.00690	¾	11.7810	11.045	⅝	33.3794	88.664	¾	62.0465	306.35
	.392699	.01227	13-16	11.9773	11.416	¾	33.7721	90.763	⅞	62.4392	310.24
	.490874	.01917	⅞	12.1737	11.793	⅞	34.1648	92.886	20.	62.8319	314.16
	.589049	.02761	15-16	12.3700	12.177	11.	34.5575	95.033	⅛	63.2246	318.10
	.687223	.03758	4.	12.5664	12.566	⅛	34.9502	97.205	¼	63.6173	322.06
	.785398	.04909	1-16	12.7627	12.962	¼	35.3429	99.402	⅜	64.0100	326.05
	.883573	.06213	⅛	12.9591	13.364	⅜	35.7356	101.62	½	64.4026	330.06
	.981748	.07670	3-16	13.1554	13.772	½	36.1283	103.87	⅝	64.7953	334.10
	1.07992	.09281	¼	13.3518	14.186	⅝	36.5210	106.14	¾	65.1880	338.16
	1.17810	.11045	5-16	13.5481	14.607	¾	36.9137	108.43	⅞	65.5807	342.25
	1.27627	.12962	⅜	13.7445	15.033	⅞	37.3064	110.75	21.	65.9734	346.36
	1.37445	.15033	7-16	13.9408	15.466	12.	37.6991	113.10	⅛	66.3661	350.50
	1.47262	.17257	½	14.1372	15.904	⅛	38.0918	115.47	¼	66.7588	354.66
	1.57080	.19635	9-16	14.3335	16.349	¼	38.4845	117.86	⅜	67.1515	358.84
	1.66897	.22166	⅝	14.5299	16.800	⅜	38.8772	120.28	½	67.5442	363.05
	1.76715	.24850	11-16	14.7262	17.257	½	39.2699	122.72	⅝	67.9369	367.28
	1.86532	.27688	¾	14.9226	17.721	⅝	39.6626	125.19	¾	68.3296	371.54
	1.96350	.30680	13-16	15.1189	18.190	¾	40.0553	127.68	⅞	68.7223	375.83
	2.06167	.33824	⅞	15.3153	18.665	⅞	40.4480	130.19	22.	69.1150	380.13
	2.15984	.37122	15-16	15.5116	19.147	13.	40.8407	132.73	⅛	69.5077	384.46
	2.25802	.40574	5.	15.7080	19.635	⅛	41.2334	135.30	¼	69.9004	388.82
	2.35619	.44179	1-16	15.9043	20.129	¼	41.6261	137.89	⅜	70.2931	393.20
	2.45437	.47937	⅛	16.1007	20.629	⅜	42.0188	140.50	½	70.6858	397.61
	2.55254	.51849	3-16	16.2970	21.135	½	42.4115	143.14	⅝	71.0785	402.04
	2.65072	.55914	¼	16.4934	21.648	⅝	42.8042	145.80	¾	71.4712	406.49
	2.74889	.60132	5-16	16.6897	22.166	¾	43.1969	148.49	⅞	71.8639	410.97
	2.84707	.64504	⅜	16.8861	22.691	⅞	43.5896	151.20	23.	72.2566	415.48
	2.94524	.69029	7-16	17.0824	23.221	14.	43.9823	153.94	⅛	72.6493	420.00
	3.04342	.73708	½	17.2788	23.758	⅛	44.3750	156.70	¼	73.0420	424.56
	3.14159	.78540	9-16	17.4751	24.301	¼	44.7677	159.48	⅜	73.4347	429.13
	3.33794	.88664	⅝	17.6715	24.850	⅜	45.1604	162.30	½	73.8274	433.74
	3.53429	.99402	11-16	17.8678	25.406	½	45.5531	165.13	⅝	74.2201	438.36
	3.73064	1.1075	¾	18.0642	25.967	⅝	45.9458	167.99	¾	74.6128	443.01
	3.92699	1.2272	13-16	18.2605	26.535	¾	46.3385	170.87	⅞	75.0055	447.69
	4.12334	1.3530	⅞	18.4569	27.109	⅞	46.7312	173.78	24.	75.3982	452.39
	4.31969	1.4849	15-16	18.6532	27.688	15.	47.1239	176.71	⅛	75.7909	457.11
	4.51604	1.6230	6.	18.8496	28.274	⅛	47.5166	179.67	¼	76.1836	461.86
	4.71239	1.7671	⅛	19.2423	29.465	¼	47.9093	182.65	⅜	76.5763	466.64
	4.90874	1.9175	¼	19.6350	30.680	⅜	48.3020	185.66	½	76.9690	471.44
	5.10509	2.0739	⅜	20.0277	31.919	½	48.6947	188.69	⅝	77.3617	476.26
	5.30144	2.2365	½	20.4204	33.183	⅝	49.0874	191.75	¾	77.7544	481.11
	5.49779	2.4053	⅝	20.8131	34.472	¾	49.4801	194.83	⅞	78.1471	485.98
	5.69414	2.5802	¾	21.2058	35.785	⅞	49.8728	197.93	25.	78.5398	490.87
	5.89049	2.7612	⅞	21.5984	37.122	16.	50.2655	201.06	⅛	78.9325	495.79
	6.08684	2.9483	7.	21.9911	38.485	⅛	50.6582	204.22	¼	79.3252	500.74
	6.28319	3.1416	⅛	22.3838	39.871	¼	51.0509	207.39	⅜	79.7179	505.71
	6.47953	3.3410	¼	22.7765	41.282	⅜	51.4436	210.60	½	80.1106	510.71
	6.67588	3.5466	⅜	23.1692	42.718	½	51.8363	213.82	⅝	80.5033	515.72
	6.87223	3.7583	½	23.5619	44.179	⅝	52.2290	217.08	¾	80.8960	520.77
	7.06858	3.9761	⅝	23.9546	45.664	¾	52.6217	220.35	⅞	81.2887	525.84
	7.26493	4.2000	¾	24.3473	47.173	⅞	53.0144	223.65	26.	81.6814	530.93
	7.46128	4.4301	⅞	24.7400	48.707	17.	53.4071	226.98	⅛	82.0741	536.05
	7.65763	4.6664	8.	25.1327	50.265	⅛	53.7998	230.33	¼	82.4668	541.19
	7.85398	4.9087	⅛	25.5254	51.849	¼	54.1925	233.71	⅜	82.8595	546.35
	8.05033	5.1572	¼	25.9181	53.456	⅜	54.5852	237.10	½	83.2522	551.55
	8.24668	5.4119	⅜	26.3108	55.088	½	54.9779	240.53	⅝	83.6449	556.76
	8.44303	5.6727	½	26.7035	56.745	⅝	55.3706	243.98	¾	84.0376	562.00
	8.63938	5.9396	⅝	27.0962	58.426	¾	55.7633	247.45	⅞	84.4303	567.27
	8.83573	6.2126	¾	27.4889	60.132	⅞	56.1560	250.95	27.	84.8230	572.56
	9.03208	6.4918	⅞	27.8816	61.862	18.	56.5487	254.47	⅛	85.2157	577.87
	9.22843	6.7771	9.	28.2743	63.617	⅛	56.9414	258.02	¼	85.6084	583.21
	9.42478	7.0686	⅛	28.6670	65.397	¼	57.3341	261.59	⅜	86.0011	588.57
	9.62113	7.3662	¼	29.0597	67.201	⅜	57.7268	265.18	½	86.3938	593.96
	9.81748	7.6699	⅜	29.4524	69.029	½	58.1195	268.80	⅝	86.7865	599.37
	10.0138	7.9798	½	29.8451	70.882	⅝	58.5122	272.45	¾	87.1792	604.81
	10.2102	8.2958	⅝	30.2378	72.760	¾	58.9049	276.12	⅞	87.5719	610.27
	10.4065	8.6179	¾	30.6305	74.662	⅞	59.2976	279.81	28.	87.9646	615.75
	10.6029	8.9462	⅞	31.0232	76.589	19.	59.6903	283.53	⅛	88.3573	621.26
	10.7992	9.2806	10.	31.4159	78.540	⅛	60.0830	287.27	¼	88.7500	626.80

For decimal equivalents of fractions of an inch or other unit, see Table No. 15.

Area × depth = contents of Round Tanks in cubic feet. (a)
(a) × 7.48 = " " " " " gallons.
(a) × .031 = " " " " " tons of water.

For contents in any other measure multiply (a) by proper equivalent in Table No. 32, 33 or 34.

Table No. 54A.

[illegible] AND AREAS OF CIRCLES FOR EACH UNIT [illegible] UNIT IN DIAMETER, FROM

28 3-8 to 66 3-4

INCLUSIVE

Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.

Table No. 54B.

CIRCUMFERENCES AND AREAS OF CIRCLES FOR EACH UNIT AND FREQUENTLY USED FRACTION OF A UNIT IN DIAMETER FROM

66 7-8 to 100.

INCLUSIVE.

Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.	Diam.	Circumf.	Area.
210.094	3512.5	75¼	236.405	4447.4	83⅝	262.716	5492.4	92.	289.027	6647.6
210.487	3525.7	⅜	236.798	4462.2	¾	263.108	5508.8	⅛	289.419	6665.7
210.879	3538.8	½	237.190	4477.0	⅞	263.501	5525.3	¼	289.812	6683.8
211.272	3552.0	⅝	237.583	4491.8	84.	263.894	5541.8	⅜	290.205	6701.9
211.665	3565.2	¾	237.976	4506.7	⅛	264.286	5558.3	½	290.597	6720.1
212.058	3578.5	⅞	238.368	4521.5	¼	264.679	5574.8	⅝	290.990	6738.2
212.450	3591.7	76.	238.761	4536.5	⅜	265.072	5591.4	¾	291.383	6756.4
212.843	3605.0	⅛	239.154	4551.4	½	265.465	5607.9	⅞	291.775	6774.7
213.236	3618.3	¼	239.546	4566.4	⅝	265.857	5624.5	93.	292.168	6792.9
213.628	3631.7	⅜	239.939	4581.3	¾	266.250	5641.2	⅛	292.561	6811.2
214.021	3645.0	½	240.332	4596.3	⅞	266.643	5657.8	¼	292.954	6829.5
214.414	3658.4	⅝	240.725	4611.4	85.	267.035	5674.5	⅜	293.346	6847.8
214.806	3671.8	¾	241.117	4626.4	⅛	267.428	5691.2	½	293.739	6866.1
215.199	3685.3	⅞	241.510	4641.5	¼	267.821	5707.9	⅝	294.132	6884.5
215.592	3698.7	77.	241.903	4656.6	⅜	268.213	5724.7	¾	294.524	6902.9
215.984	3712.2	⅛	242.295	4671.8	½	268.606	5741.5	⅞	294.917	6921.3
216.377	3725.7	¼	242.688	4686.9	⅝	268.999	5758.3	94.	295.310	6939.8
216.770	3739.3	⅜	243.081	4702.1	¾	269.392	5775.1	⅛	295.702	6958.2
217.163	3752.8	½	243.473	4717.3	⅞	269.784	5791.9	¼	296.095	6976.7
217.555	3766.4	⅝	243.866	4732.5	86.	270.177	5808.8	⅜	296.488	6995.3
217.948	3780.0	¾	244.259	4747.8	⅛	270.570	5825.7	½	296.881	7013.8
218.341	3793.7	⅞	244.652	4763.1	¼	270.962	5842.6	⅝	297.273	7032.4
218.733	3807.3	78.	245.044	4778.4	⅜	271.355	5859.6	¾	297.666	7051.0
219.126	3821.0	⅛	245.437	4793.7	½	271.748	5876.5	⅞	298.059	7069.6
219.519	3834.7	¼	245.830	4809.0	⅝	272.140	5893.5	95.	298.451	7088.2
219.911	3848.5	⅜	246.222	4824.4	¾	272.532	5910.6	⅛	298.844	7106.9
220.304	3862.2	½	246.615	4839.8	⅞	272.926	5927.6	¼	299.237	7125.6
220.697	3876.0	⅝	247.008	4855.2	87.	273.319	5944.7	⅜	299.629	7144.3
221.090	3889.8	¾	247.400	4870.7	⅛	273.711	5961.8	½	300.022	7163.0
221.482	3903.6	⅞	247.793	4886.2	¼	274.104	5978.9	⅝	300.415	7181.8
221.875	3917.5	79.	248.186	4901.7	⅜	274.497	5996.0	¾	300.807	7200.6
222.268	3931.4	⅛	248.579	4917.2	½	274.889	6013.2	⅞	301.200	7219.4
222.660	3945.3	¼	248.971	4932.7	⅝	275.282	6030.4	96.	301.593	7238.2
223.053	3959.2	⅜	249.364	4948.3	¾	275.675	6047.6	⅛	301.986	7257.1
223.446	3973.1	½	249.757	4963.9	⅞	276.067	6064.9	¼	302.378	7276.0
223.838	3987.1	⅝	250.149	4979.5	88.	276.460	6082.1	⅜	302.771	7294.9
224.231	4001.1	¾	250.542	4995.2	⅛	276.853	6099.4	½	303.164	7313.8
224.624	4015.2	⅞	250.935	5010.9	¼	277.246	6116.7	⅝	303.556	7332.8
225.017	4029.2	80.	251.327	5026.5	⅜	277.638	6134.1	¾	303.949	7351.8
225.409	4043.3	⅛	251.720	5042.3	½	278.031	6151.4	⅞	304.342	7370.8
225.802	4057.4	¼	252.113	5058.0	⅝	278.424	6168.8	97.	304.734	7389.8
226.195	4071.5	⅜	252.506	5073.8	¾	278.816	6186.2	⅛	305.127	7408.9
226.587	4085.7	½	252.898	5089.6	⅞	279.209	6203.7	¼	305.520	7428.0
226.980	4099.8	⅝	253.291	5105.4	89.	279.602	6221.1	⅜	305.913	7447.1
227.373	4114.0	¾	253.684	5121.2	⅛	279.994	6238.6	½	306.305	7466.2
227.765	4128.2	⅞	254.076	5137.1	¼	280.387	6256.1	⅝	306.698	7485.3
228.158	4142.5	81.	254.469	5153.0	⅜	280.780	6273.7	¾	307.091	7504.5
228.551	4156.8	⅛	254.862	5168.9	½	281.173	6291.2	⅞	307.483	7523.7
228.944	4171.1	¼	255.254	5184.9	⅝	281.565	6308.8	98.	307.876	7543.0
229.336	4185.4	⅜	255.647	5200.8	¾	281.958	6326.4	⅛	308.269	7562.2
229.729	4199.7	½	256.040	5216.8	⅞	282.351	6344.1	¼	308.661	7581.5
230.122	4214.1	⅝	256.433	5232.8	90.	282.743	6361.7	⅜	309.054	7600.8
230.514	4228.5	¾	256.825	5248.9	⅛	283.136	6379.4	½	309.447	7620.1
230.907	4242.9	⅞	257.218	5264.9	¼	283.529	6397.1	⅝	309.840	7639.5
231.300	4257.4	82.	257.611	5281.0	⅜	283.921	6414.9	¾	310.232	7658.9
231.692	4271.8	⅛	258.003	5297.1	½	284.314	6432.6	⅞	310.625	7678.3
232.085	4286.3	¼	258.396	5313.3	⅝	284.707	6450.4	99.	311.018	7697.7
232.478	4300.8	⅜	258.789	5329.4	¾	285.100	6468.2	⅛	311.410	7717.1
232.871	4315.4	½	259.181	5345.6	⅞	285.492	6486.0	¼	311.803	7736.6
233.263	4329.9	⅝	259.574	5361.8	91.	285.885	6503.9	⅜	312.196	7756.1
233.656	4344.5	¾	259.967	5378.1	⅛	286.278	6521.8	½	312.588	7775.6
234.049	4359.2	⅞	260.359	5394.3	¼	286.670	6539.7	⅝	312.981	7795.2
234.441	4373.8	83.	260.752	5410.6	⅜	287.063	6557.6	¾	313.374	7814.8
234.834	4388.5	⅛	261.145	5426.9	½	287.456	6575.5	⅞	313.767	7834.4
235.227	4403.1	¼	261.538	5443.3	⅝	287.848	6593.5	100.	314.159	7854.0
235.619	4417.9	⅜	261.930	5459.6	¾	288.241	6611.5			
236.012	4432.6	½	262.323	5476.0	⅞	288.634	6629.6			

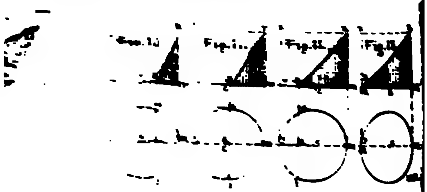
For decimal equivalents of fractions of an inch or other unit, see Table No. 15.

Area × depth = contents of Round Tanks in cubic feet. (a)
(a) × 7.48 = " " " " " gallons.
(a) × .031 = " " " " " tons of water.
For contents in any other measure multiply (a) by proper *equivalent in Table No. 32, 33, or 34.*

MENSURATION OF SOLIDS.

MEASURE.

ARRANGED ALPHABETICALLY.



UNGULAS

base one-half sum of greatest

perpendicular heights or area

—see figure 6.

cross-section at right angles to

one-half sum of greatest and

heights or lengths.

—see

plane cuts or touches base

proceed as follows.

area a d m b

Cube.

$$\left.\begin{array}{c}\text{Volume}\\ \text{or}\\ \text{Contents}\end{array}\right\} = \left\{\begin{array}{l}\text{cube of length of one edge or}\\ 1.90985 \times \text{volume of an inscribed sphere, or}\\ 1.27324 \times \text{volume of an inscribed cylinder, or}\\ 3.81972 \times \text{volume of an insci ibed cone.}\end{array}\right.$$

The diagonal of a cube = 1.732 × length of one edge.

" " " " = diameter of a circumscribed sphere.

Cylinder.—Circular or elliptic, right or oblique.

$$\left.\begin{array}{c}\text{Volume}\\ \text{or}\\ \text{Contents}\end{array}\right\} = \left\{\begin{array}{l}\text{area of one end} \times \text{perpendicular distance}\\ \quad\text{to the other end, or}\\ \text{area of cross-section perpendicular to the}\\ \quad\text{sides} \times \text{the actual length of the sides, or}\\ 3 \times \text{volume of cone whose base and height}\\ \quad\text{are = those of the cylinder.}\end{array}\right.$$

Ellipsoid.—(Sometimes called a spheroid.) Is a solid generated by the revolution of an ellipse around either its short or long diameter.

When generated around its short diameter it is called an oblate ellipsoid.

When generated around its long diameter it is called an oblong or prolate ellipsoid.

$$\left.\begin{array}{c}\text{Volume or Contents}\\ \text{of either Ellipsoid}\end{array}\right\} = \left\{\begin{array}{l}\text{square of the revolving diam-}\\ \quad\text{eter} \times \text{fixed diameter} \times .5236.\end{array}\right.$$

Frustum of a Cone or Pyramid. (With base and top parallel.) Regular or irregular, right or oblique.

Let B represent base; T the Top; P the perpendicular distance between B and T; and C represent section parallel to and midway between B and T.

We then have:

$$\left.\begin{array}{c}\text{Volume}\\ \text{or}\\ \text{Contents}\end{array}\right\} = \left\{\begin{array}{l}(\text{area B} + \text{area T} + \text{mean proportional}\\ \quad\text{between them}) \times \tfrac{1}{3}\text{P, or}\\ (\text{area B} + \text{area T} + \sqrt{\text{area B} \times \text{area T}})\\ \quad \times \tfrac{1}{3}\text{P or}\\ (\text{area B} + \text{area T} + [4 \times \text{area C}]) \times \tfrac{1}{6}\text{P.}\end{array}\right.$$

Frustum of a cylinder:—see prism, frustum of.
Frustum of a prism:—see prisims, frustum of.
Frustum of a wedge—prismoid, see wedge, frustum of.
Irregular Solid.

Volume or Contents = area of generating surface × length of arc described by centre of gravity of the generating surface. If the arc described by the centre of gravity is 360° or a circumference, the volume = area of generating surface × 6.283186 × radius.*

*Radius = distance of centre of gravity of the figure from the axis of revolution. Axis may be one of the sides of the figure or any other axis. Radius must be measured perpendicular to axis. To find centre of gravity quickly, cut out to scale on card board or *pattern lumber, the generating* figure, and balance on a point.

Paraboloid — A solid generated by the revolution of a parabola.

Volume of paraboloid = Area of base × ½ height or radius of base squared × height × 1.5708.

Paraboloid — Frustum of (ends perpendicular to axis.)

Volume = (Square of diameter of small end + square of diameter of large end) × perpendicular distance between the ends × .3927.

Parallelopipedon — A parallelopipedon is any solid bounded by six sides each of which is a parallelogram and the opposite pairs parallel to each other.

Volume = area of any one face × perpendicular distance to the opposite face. A cube is one of the parallelopipedons; its volume etc. is hereinbefore given.

Table No. 55.

A polyhedron (regular) is one which ... solid angles respectively similar ... They are

... having 4 sides, each an equilateral ...

... cube, having 6 sides, each a ...

... having 8 sides, an equilateral ...

... having 12 sides, each an equi...

... having 20 sides, each an equi...

... length one edge ... 1.

ism or Cylinder.—Frustum of.

lume or contents of any frustum of any prism or der = area base × perpendicular height from base tre of gravity* of top.

sm, Frustum of,†

en a cross-section of prism at right angles to its is a square, parallelogram, regular polygon or a le.

ne or ents = { area of cross-section, perpendicular to sides × average height‡ of prism.

moids.—See wedge, frustum of.

g.

ne or ents = { Thickness + inner diameter × square of thickness × 2½ or more accurately, Area of section of ring × ½ (inside diameter + outside diameter) × 3.14159.

e.

me = nts |
cube of diameter × .5236 or
" " radius × 4.189 or
" " circumference × .01689 or
area surface × ⅙ diameter or
" great circle × ⅔ diameter or
⅔ volume of circumscribing cylinder or
.5236 × volume of circumscribing cube.

ere.—Segment of.

e or nts = { (Square of height + 3 × square of radius of base) × (height × .5236.)

ere.—Zone of.

me = nts { | square of radius of base + square of radius of top + ⅓ square of height | × height × 1.5708.

ere.—Hollow.

e or nts = { contents of sphere of outside diameter — contents of sphere of inside diameter.

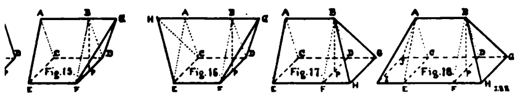


Fig. 13. Fig. 16. Fig. 17. Fig. 18.

re are three kinds of wedges.

—Figure 14. Edge AB. parallel with and equal or C D, the length of the back CDEF.

—Figures 15 and 16. Edge greater in length ength of back.

—Figures 17 and 18. Edge less in length than of back.

* centre of gravity graphically or cut out top, to scale on ard on pattern lumber, and balance on a point.

† two ends are assumed to be top and base of prism and inclined or not toward or from each other.

‡ *age height = sum of the* lengths of all the vertical edges *by the number of edges.*

[illegible] contents of any [illegible]

[illegible] the length of the back [illegible] the length [illegible] the breadth of the [illegible] the altitude of the [illegible] will be the volume or [illegible]

[illegible] formula," the [illegible] than any other by [illegible] of embankments or [illegible]

[illegible] has found that in nine [illegible] sufficient to [illegible] considerable [illegible] divid- [illegible] embankment, excava- [illegible] plain [illegible] can be easily computed and [illegible]

[illegible] the wedge is simply a triangu- [illegible] and height AF or EF and its [illegible]

[illegible] the wedge can be divided into [illegible] EF and a pyramid with [illegible] base EDF equals in area [illegible] required while the height [illegible] length of back.

[illegible] of pyramid we [illegible] wedge.

[illegible] one right triangular [illegible] one with base AEC [illegible] base BDF equals [illegible] the three volumes we [illegible] the wedge.

[illegible] one right triangular [illegible] EF and one pyramid with base DGFH [illegible]

[illegible] one right triangular [illegible] pyramids as shown.

[illegible] happens that the centre of gravity [illegible] of the ends of the wedge is known or [illegible] graphically in a moment. In such cases, [illegible] area of a cross-section perpendicular to the [illegible] distance between the centres of gravity of [illegible]

Wedge. Frustum of, or Prismoid.—The general rule to find the volume or contents is as follows:

Rule or Prismoidal Formula.*

Find the sum of the areas of the extreme sections or ends and four times the middle section, multiply the result by one-sixth of the distance between the extreme sections, the result will be the volume or contents required. Expressed algebraically the rule is as follows:

$$\text{Volume or Contents} = \begin{cases} L \times \dfrac{A + B + 4M}{6} \text{ or} \\ \text{Length} \times \text{mean area of cross-section.} \end{cases}$$

In the above expressson L = perpendicular distance between ends. A = area of one of the parallel ends. B = area of the the other parallel end. M = area of cross-section midway between A and B and parallel to them.

The prismoidal formula* is of very extensive applicaion. It can be shown that the volume of many of the figures hereinbefore considered can be computed by it.

EXAMPLE.—Pyramid.

Base = one end: vertex = the other end, (area o.) Sum = area of base. Area of section midway between = ¼ base; hence 4 × middle section = base. Length = height.

∴ we have by the prismoidal formula, volume =

$$\frac{\text{base} + 0 + \text{base}}{6} \times \text{height} = \tfrac{1}{3}\ \text{base} \times \text{height}.$$

Among other figures the formula applies to a sphere, hemisphere, spherical segment, frustum of cone etc. also to a section of cone, or frustum of such section, where cutting plane passes through VERTEX and BASE.

The rule also applies to a cylinder when the cutting plane is parallel to the sides and passes through both ends. If cutting plane is oblique, extend it and cylinder, if necessary, until the plane cuts the sides of the cylinder.

Use rule for Ungulas for sections formed, subtracting the volume of the small one.

Though above rule, with oblique cutting plane, is not strictly correct, error will seldom exceed one per cent.

*See under 'EMBANKMENTS" for quick methods of computing the volume of certain "cuts" and "fills" from the profile, avoiding delays in making estimates and expense for extra time needed in using for formula. In many cases this extra expense exceeds the cost to construct or avoid the per cent of earth work, the quick *methods may give in* error for or against the contractor.

PLANE TRIGONOMETRY.

TRIGOMETRIC FUNCTIONS.

From the sexagesimal division of a circle or circumference as given by Table No. 19, we have:

1 circumference $= 360^\circ = 21600' = 1296000''$.

In the CENTESIMAL DIVISION, of a circle or circumference,

The circumference is divided into 400 grades.

" grade " " " 100 minutes.

" minute " " " 100 seconds.

Hence 1 circumference $= 400$ grades $= 40000$ minutes $= 4000000$ seconds or as abbreviated $= 400$ gr $= 40000' = 4000000''$.

Though much more convenient this system is not in general use because of the difficulty of changing all existing tables etc., to correspond with it.

Radian. -In higher mathematical investigations, where no division into degrees etc., is required, the radius is taken as the UNIT OF MEASURE. This UNIT is ∴ the angle subtended by an arc equal in length to the radius, and is called the RADIAN.

Ratio of circumference to diameter (from geometry) $= 3.14159265$, called π.*

∴ ratio of circumference to the radius ($\frac{1}{2}$ diameter) $= 2 \times 3.14159265 = 6.2831853$.

∴ 360° (whole circumference) $\div 6.2831853 = 57.2957795^\circ$.

∴ one radian $= 57.2957795$ degrees.

$= 3437.74677$ minutes.

$= 206264.806$ seconds.

$$\pi = \frac{\text{circumference}}{\text{diameter}} = \frac{\frac{1}{2}\text{ circumference}}{\text{radius}} = 3.14159265.$$

Therefore when the Radian is used as a unit,

$\frac{1}{2}\pi$ represents an angle of 90°

π " " " " 180°

2π " " " " $360^\circ =$ circumference.

$2\pi n$ " " " " n circumferences.

*See Table No. 49.

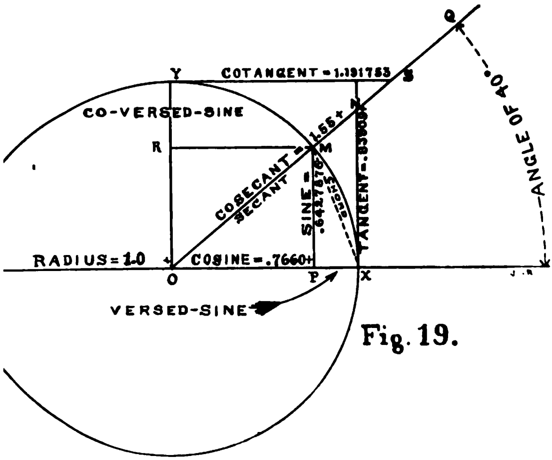


Fig. 19.

Figure 19 shows the different trigometric expressions the angle S O X.* In the figure it is drawn equal to ° and the values placed opposite, certain of the pressions are for angle of 40° and radius 1.

The complement of an angle = its difference from 90°.
" supplement " " " = " " " 180°.

Abbreviations.

Sin	for sine	= the line PM, figure 19.
Cos	" cosine	= " " OP, " "
Tan	" tangent	= " " NX, " "
Cot	" cotangent	= " " YS, " "
Sec	" secant	= " " ON. " "
Cosec	" cosecant	= " " OS, " "
Versin	" versed-sine	= " " PX, " "
Coversin	" co-versed-sine	= " " RY, " "
R or rad.	" radius	= " " TO, " "
Ch	" chord	= dotted " MX, " "

Trigometric Formulae.—In the following formulae the radius = 1.

$$\text{Sin} = \frac{1}{\text{Cosec}} = \frac{\text{cos}}{\text{cot}} = \sqrt{1 - \text{cos}^2}$$

$$\text{Tan} = \frac{\text{sin}}{\text{cos}} = \frac{1}{\text{cot}} \quad \left(\begin{array}{l}\text{tan of } 90° \text{ is infinite.} \\ \text{" " } 180° \text{ is zero.}\end{array}\right)$$

$$\text{Cos} = \sqrt{1 - \text{sin}^2} = \frac{\text{sin}}{\text{tan}} = \text{sin} \times \text{cot} = \frac{1}{\text{sec}}$$

$$\text{Sec} = \sqrt{\text{rad}^2 + \text{tan}^2} = \frac{1}{\text{cos}} = \frac{\text{tan}}{\text{sin}}$$

*For length of arc (curved line M X) see Table No. 49.

$$\text{Cot} = \frac{\cos}{\sin} = \frac{1}{\tan}$$

$$\text{Cosec} = \frac{1}{\sin}$$

Versin = rad—cos = 1—cos.

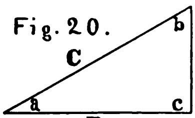
Coversin = rad—sin = 1—sin.

Radius = 1 = tan $\times$ cot = $\sqrt{\sin^2 + \cos^2}$

ch = radius $\times$ 2 $\times$ sine of one-half the angle.

RIGHT-ANGLED TRIANGLE.

Fig. 20.



In figure 20 the side marked C is called the hypothenuse, B the base, and A the altitude.

$C^2 = A^2 + B^2$	$A^2 = C^2 - B^2$	$B^2 = C^2 - A^2$
$C = \sqrt{A^2 + B^2}$	$A = \sqrt{C^2 - B^2}$	$B = \sqrt{C^2 - A^2}$

A = C $\times$ sin a = B $\times$ tan a = C $\times$ cos b = B $\times$ cot b.

B = C $\times$ cos a = A $\times$ cot a   C $\times$ sin b   A $\times$ tan b.

C = A $\times$ cosec a = B $\times$ sec a = A $\times$ sec b = B $\times$ cosec b.

Expressing the above formulae in words we have for a right angled triangle the following theorms.

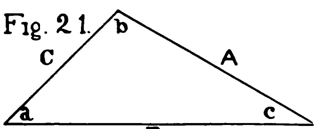
1st.—The hypothenuse of any right angled triangle is equal to a side into the secant of its adjacent angle or the cosecant of its opposite angle.

2d.—A side is equal to the hypothenuse into the sine of the opposite angle or the cosine of the adjacent angle.

3d.—One side is equal to the other side into the tangent of the angle adjacent to that other side or to the cotangent of the angle adjacent to itself.

OBLIQUE ANGLED TRIANGLES.

Fig. 21.



The sides of a triangle are proportional to the sines of their opposite angles or from figure 21 we have.

Side A : Side B : Side C :: Angle a : Angle b : Angle c.

We also have $\frac{A}{\text{Sin a}}$, $\frac{B}{\text{Sin b}}$ and $\frac{C}{\text{Sin c}}$ =to each other

This common quotiont is called the modulus of the *triangle* and is equal to the diameter of the circumscrib*ed circle*. Its abbreviation is M.

...RMULAE FOR SOLUTION OF PLANE TRIANGLES.

See Figure 21.

...en	Required.	Formulae.
C, ree .	a, one angle.	Let. $s = \frac{1}{2}(A + B + C)$. $\text{Tan}\ \frac{1}{2}\ a = \sqrt{\frac{(s - B)(s - C)}{s\,(s - A)}}$.
	a, b, c, all the angles.	Let $h = \sqrt{\frac{(s-A)(s-B)(s-C)}{s}}$ $\text{Tan}\ \frac{1}{2}\ a = \frac{h}{s - A}$, $\text{Tan}\ \frac{1}{2}\ b = \frac{h}{s - B}$. $\text{Tan}\ \frac{1}{2}\ c = \frac{h}{s - C}$ Checks. $a + b + c = 180^\circ$. $\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c} =$ modulus.
ı, .es ıe ed .	b and c, the other angles.	$\text{Tan}\ \frac{1}{2}\ (b-c) = \frac{B-C}{B+C}\ \cot\ \frac{1}{2}\ a$. $\frac{1}{2}\ (b+c) = 90^\circ - \frac{1}{2}\ a$. $b = \frac{1}{2}\ (b+c) + \frac{1}{2}(b-c)$. $c = \frac{1}{2}\ (b+c) - \frac{1}{2}(b-c)$. Check, as above.
	A, b, c, the remaining parts.	$A \sin \frac{1}{2}\ (b-c) = (B - C) \cos \frac{1}{2}\ a$. $A \cos \frac{1}{2}\ (b-c) = (B + C) \sin \frac{1}{2}\ a$. Having found A and $\frac{1}{2}(b-c)$, proceed as in the case next above.
a, ides the oppo- ne of m.	C, b, c, the remain- ing parts.	$\text{Sin}\ b = \frac{B}{A} \sin\ a$. (two values of b.) $c = 180^\circ - (a + b)$. $C = \frac{B \sin c}{\sin b} = \frac{A \sin c}{\sin a}$
ı, b, side any ngles.	B, C, c, the remain- ing parts.	$c = 180^\circ - (a + b)$, $B = \frac{A \sin b}{\sin a}$. $C = \frac{A \sin c}{\sin a} = \frac{A \sin (a + b)}{\sin a}$

‹ *Cot* = *Cos* × Sec = Sin × Cosec = 1.

a + *Angle* b + Angle c = 180.°

$Cot = \frac{cos}{sin} = \frac{1}{tan}$

$Cosec = \frac{1}{sin}$

Versin = rad — cos = 1 — cos.

Coversin = rad — sin = 1 — sin.

Radius = 1 = tan × cot = $\sqrt{sin^2 + cos^2}$

Ch = radius × 2 × sine of one-half the angle.

Right-Angled Triangle.

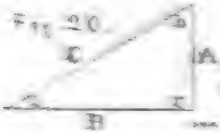


Fig. 20.

In figure 20 the side mark is called the hypothenuse, B base, and A the altitude.

$C^2 = A^2 + B^2$	$A^2 = C^2 - B^2$	$B^2 = C^2$
$C = \sqrt{A^2 + B^2}$	$A = \sqrt{C^2 - B^2}$	$B = \sqrt{C^2}$

A = C × sin a = B × tan a = C × cos b = B × co

B = C × cos a = A × cot a = C × sin b = A × ta

C = A × cosec a = B × sec a = A × sec b = B × co

Expressing the above formulae in words we hav right angled triangle the following theorms.

1st. The hypothenuse of any right angled trian equal to a side into the secant of its adjacent ang the cosecant of its opposite angle.

2d. A side is equal to the hypothenuse into th of its opposite angle or the cosine of the adj angle.

Formulae for Solution of Plane Triangles.

See Figure 21.

Given	Required.	Formulae.
A. B, C, the three sides.	a, one angle.	Let $s = \frac{1}{2}(A + B + C)$. $\tan \frac{1}{2} a = \sqrt{\frac{(s - B)(s - C)}{s(s - A)}}$.
	a, b, c, all the angles.	Let $h = \sqrt{\frac{(s-A)(s-B)(s-C)}{s}}$ $\tan \frac{1}{2} a = \frac{h}{s - A}$, $\tan \frac{1}{2} b = \frac{h}{s - B}$. $\tan \frac{1}{2} c = \frac{h}{s - C}$ Checks. $a + b + c = 180°$. $\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c} =$ modulus.
B, C, a, two sides and the included angle.	b and c, the other angles.	$\tan \frac{1}{2}(b-c) = \frac{B-C}{B+C} \cot \frac{1}{2} a$. $\frac{1}{2}(b+c) = 90° - \frac{1}{2} a$. $b = \frac{1}{2}(b+c) + \frac{1}{2}(b-c)$. $c = \frac{1}{2}(b+c) - \frac{1}{2}(b-c)$. Check, as above.
	A, b, c, the remaining parts.	$A \sin \frac{1}{2}(b-c) = (B - C)\cos \frac{1}{2} a$. $A \cos \frac{1}{2}(b-c) = (B + C)\sin \frac{1}{2} a$. Having found A and $\frac{1}{2}(b-c)$, proceed as in the case next above.
A, B, a, two sides and the angle opposite one of them.	C, b, c, the remaining parts.	$\sin b = \frac{B}{A} \sin a$. (two values of b.) $c = 180° - (a + b)$. $C = \frac{B \sin c}{\sin b} = \frac{A \sin c}{\sin a}$
A, a, b, one side and any two angles.	B, C, c, the remaining parts.	$c = 180° - (a + b)$. $B = \frac{A \sin b}{\sin a}$. $C = \frac{A \sin c}{\sin a} = \frac{A \sin (a + b)}{\sin a}$

Tan × Cot = Cos × Sec = Sin × Cosec = 1.
Angle a + Angle b + Angle c = 180.°

CAUTIONS.

... determine an angle by its
... accurately determin
... the sine.
... after obtaining the
... independentl
... check.
... above all a
... well.
... be sure a
... on the map.
... transit be posi
... on the sea
... right direction.
... bearing, on wo
... needle in bu
... CURR
... OF AUTOMOB
... When you mi
... from the moto
... Neith
... cushions
... most of its m
... needle
... stickin
... has lost i
... instrument should
... unless you ha

... better yo
... check without
... accuracy h

Table No. 56.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Dep. 0 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 0 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·0000000	·000000	Infinite.	1·000000	60
1	·0002909	·000291	3437·746	1·000000	59
2	·0005818	·000582	1718·873	·9999998	58
3	·0008727	·000872	1145·915	·9999996	57
4	·0011636	·001163	859·4363	·9999993	56
5	·0014544	·001454	687·5488	·9999989	55
6	·0017453	·001745	572·9572	·9999985	54
7	·0020362	·002036	491·1060	·9999979	53
8	·0023271	·002327	429·7175	·9999973	52
9	·0026180	·002618	381·9709	·9999966	51
10	·0029089	·002908	343·7737	·9999958	50
11	·0031998	·003199	312·5213	·9999949	49
12	·0034907	·003490	286.4777	·9999939	48
13	·0037815	·003781	264·4408	·9999928	47
14	·0040724	·004072	245.5519	·9999917	46
15	·0043633	·004363	229·1816	·9999905	45
16	·0046542	·004654	214·8576	·9999892	44
17	·0049451	·004945	202·2187	·9999878	43
18	·0052360	·005236	190·9841	·9999863	42
19	·0055268	·005526	180·9322	·9999847	41
20	·0058177	·005817	171·8854	·9999831	40
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·0061086	·006108	163·7001	·9999813	39
22	·0063995	·006399	156·2590	·9999795	38
23	·0066904	·006690	149·4650	·9999776	37
24	·0069813	·006981	143·2371	·9999756	36
25	·0072721	·007272	137·5075	·9999736	35
26	·0075630	·007563	132·2185	·9999714	34
27	·0078539	·007854	127·3213	·9999692	33
28	·0081448	·008145	122·7739	·9999668	32
29	·0084357	·008436	118·5401	·9999644	31
30	·0087265	·008726	114·5886	·9999619	30
31	·0090174	·009017	110·8920	·9999593	29
32	·0093083	·009308	107·4264	·9999567	28
33	·0095992	·009599	104·1709	·9999539	27
34	·0098900	·009890	101·1069	·9999511	26
35	·0101809	·010181	98·21794	·9999482	25
36	·0104718	·010472	95·48947	·9999452	24
37	·0107627	·010763	92·90848	·9999421	23
38	·0110535	·011054	90·46333	·9999389	22
39	·0113444	·011345	88·14357	·9999357	21
40	·0116353	·011636	85·93979	·9999323	20
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·0119261	·011927	83·84350	·9999289	19
42	·0122170	·012217	81·84704	·9999254	18
43	·0125079	·012508	79·94343	·9999218	17
44	·0127987	·012799	78·12634	·9999181	16
45	·0130896	·013090	76·39000	·9999143	15
46	·0133805	·013381	74·72916	·9999105	14
47	·0136713	·013672	73·13899	·9999065	13
48	·0139622	·013963	71·61507	·9999025	12
49	·0142530	·014254	70·15334	·9998984	11
50	·0145439	·014545	68·75008	·9998942	10
51	·0148348	·014836	67·40185	·9998900	9
52	·0151256	·015127	66·10547	·9998856	8
53	·0154165	·015418	64·85800	·9998812	7
54	·0157073	·015709	63·65674	·9998766	6
55	·0159982	·016000	62·49915	·9998720	5
56	·0162890	·016291	61·38290	·9998673	4
57	·0165799	·016582	60·30582	·9998625	3
58	·0168707	·016873	59·26587	·9998577	2
59	·0171616	·017164	58·26117	·9998527	1
60	·0174524	·017455	57·28996	·9998477	0
′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 89 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 89 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Table No. 37.

Sine	Tang	Cotang	Cosine	'	'	Sine	Tang	Cotang	Cosine	'
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41	[illegible]	[illegible]	[illegible]	[illegible]	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42	[illegible]	[illegible]	[illegible]	[illegible]	18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	[illegible]	[illegible]	17
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44	[illegible]	[illegible]	[illegible]	[illegible]	16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]	[illegible]	15
[illegible]	·025021	39·96546	·9996871	34	46	·0308263	·030813	32·43120	·9995247	14
[illegible]	·025312	39·50589	·9996798	33	47	·0311206	·031135	32·11609	·9995167	13
[illegible]	·025603	39·05677	·9996724	32	48	·0314106	·031426	31·82051	·9995066	12
[illegible]	·025894	38·61775	·9996649	31	49	·0317015	·031717	31·52836	·9994971	11
[illegible]	·026186	38·18846	·9996573	30	50	·0319922	·032006	31·24157	·9994861	10
[illegible]	·026477	37·76861	·9996497	29	51	·0322830	·032209	30·95092	·9994789	9
[illegible]	·026768	37·35769	·9996419	28	52	·0325737	·032561	30·65330	·9994693	8
[illegible]	·027059	36·95600	·9996341	27	53	·0328644	·032862	30·41158	·9994596	7
[illegible]	·027350	36·56265	·9996262	26	54	·0331552	·033173	30·14401	·9994502	6
[illegible]	·027641	36·17789	·9996182	25	55	·0334460	·033464	29·89450	·9994406	5
[illegible]	·027932	35·80055	·9996101	24	56	·0337366	·033756	29·62119	·9994308	4
[illegible]	·028223	35·43126	·9996020	23	57	·0340274	·034047	29·37110	·9994209	3
[illegible]	·028514	35·06084	·9995937	22	58	·0343181	·034338	29·12400	·9994110	2
[illegible]	·028806	34·71611	·9995854	21	59	·0346088	·034650	28·87708	·9994009	1
[illegible]	·029097	34·36777	·9995770	20	60	·0348995	·034920	28·63625	·9993908	0
Cosine.	Cotan.	Tang.	Sine.	'	'	Cosine.	Cotan.	Tang.	Sine.	'

Lat. (Read up.) Dep.

Table No. 58.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

Dep. 2 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·0348995	·034920	28·63625	·9993908	60	21	·0410037	·041038	24·36750	·9991590	39	41	·0468159	·046867	21.33685	·9989035	19
1	·0351902	·035212	28·39939	·9993806	59	22	·0412944	·041329	24·19571	·9991470	38	42	·0471065	·047158	21·20494	·9988899	18
2	·0354809	·035503	28·16642	·9993704	58	23	·0415850	·041621	24·02632	·9991350	37	43	·0473970	·047450	21·07466	·9988761	17
3	·0357716	·035794	27·93723	·9993600	57	24	·0418757	·041912	23·85927	·9991228	36	44	·0476876	·047741	20·94596	·9988623	16
4	·0360623	·036085	27·71174	·9993495	56	25	·0421663	·042203	23·69453	·9991106	35	45	·0479781	·048033	20·81882	·9988484	15
5	·0363530	·036377	27·48985	·9993390	55	26	·0424569	·042495	23·53205	·9990983	34	46	·0482687	·048325	20·69322	·9988344	14
6	·0366437	·036668	27·27148	·9993284	54	27	·0427475	·042786	23·37177	·9990859	33	47	·0485592	·048616	20·56911	·9988203	13
7	·0369344	·036959	27·05655	·9993177	53	28	·0430382	·043078	23·21366	·9990734	32	48	·0488498	·048908	20·44646	·9988061	12
8	·0372251	·037250	26·84498	·9993069	52	29	·0433288	·043369	23·05767	·9990609	31	49	·0491403	·049199	20·32530	·9987919	11
9	·0375158	·037542	26·63669	·9992960	51	30	·0436194	·043660	22·90376	·9990482	30	50	·0494308	·049491	20·20555	·9987775	10
10	·0378065	·037833	26·43160	·9992851	50	31	·0439100	·043952	22·75189	·9990355	29	51	·0497214	·049782	20·08719	·9987631	9
11	·0380971	·038124	26·22963	·9992740	49	32	·0442006	·044243	22·60201	·9990227	28	52	·0500119	·050074	19·97021	·9987486	8
12	·0383878	·038416	26·03073	·9992629	48	33	·0444912	·044535	22·45409	·9990098	27	53	·0503024	·050366	19·85459	·9987340	7
13	·0386785	·038707	25·83482	·9992517	47	34	·0447818	·044826	22·30809	·9989968	26	54	·0505929	·050657	19·74029	·9987194	6
14	·0389692	·038998	25·64183	·9992404	46	35	·0450724	·045118	22·16398	·9989837	25	55	·0508835	·050949	19·62729	·9987046	5
15	·0392598	·039290	25·45170	·9992290	45	36	·0453630	·045409	22·02171	·9989706	24	56	·0511740	·051241	19·51558	·9986898	4
16	·0395505	·039581	25·26436	·9992176	44	37	·0456536	·045701	21·88125	·9989573	23	57	·0514645	·051532	19·40513	·9986748	3
17	·0398411	·039872	25·07975	·9992060	43	38	·0459442	·045992	21·74256	·9989440	22	58	·0517550	·051824	19·29592	·9986598	2
18	·0401318	·040164	24·89782	·9991944	42	39	·0462347	·046284	21·60563	·9989306	21	59	·0520455	·052116	19·18793	·9986447	1
19	·0404224	·040455	24·71851	·9991827	41	40	·0465253	·046575	21·47040	·9989171	20	60	·0523360	·052407	19·08113	·9986295	0
20	·0407131	·040746	24·54175	·9991709	40												
′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 87 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 87 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 3 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 3 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·0523360	·052407	19·08113	·9986295	60	21	·0584352	·058536	17·08372	·9982912	39	41	·0642420	·064375	15·53398	·9979343	19
1	·0526264	·052699	18·97552	·9986143	59	22	·0587256	·058827	16·99895	·9982742	38	42	·0645323	·064667	15·46381	·9979156	18
2	·0529169	·052991	18·87106	·9985989	58	23	·0590160	·059119	16·91502	·9982570	37	43	·0648226	·064959	15·39427	·9978968	17
3	·0532074	·053282	18·76775	·9985835	57	24	·0593064	·059410	16·83191	·9982398	36	44	·0651129	·065251	15·32535	·9978779	16
4	·0534979	.053574	18·66556	·9985680	56	25	·0595967	·059702	16·74961	·9982225	35	45	·0654031	·065543	15·25705	·9978589	15
5	·0537883	·053866	18·56447	·9985524	55	26	·0598871	·059994	16·66811	·9982052	34	46	·0656934	·065835	15·18934	·9978399	14
6	·0540788	·054158	18·46447	·9985367	54	27	·0601775	·060286	16·58739	·9981877	33	47	·0659836	·066127	15·12224	·9978207	13
7	·0543693	·054449	18·36553	·9985209	53	28	·0604678	·060578	16·50745	·9981701	32	48	·0662739	·066419	15·05572	·9978015	12
8	·0546597	·054741	18·26765	·9985050	52	29	·0607582	·060870	16·42827	·9981525	31	49	·0665641	·066712	14·98978	·9977821	11
9	·0549502	·055033	18·17080	·9984891	51	30	·0610485	·061162	16·34985	·9981348	30	50	·0668544	·067004	14·92441	·9977627	10
10	·0552406	·055325	18·07497	·9984731	50	31	·0613389	·061454	16·27217	·9981170	29	51	·0671446	·067296	14·85961	·9977433	9
11	·0555311	·055616	17·98015	·9984570	49	32	·0616292	·061746	16·19522	·9980991	28	52	·0674349	·067588	14·79537	·9977237	8
12	·0558215	·055908	17.88631	·9984408	48	33	·0619196	·062038	16·11899	·9980811	27	53	·0677251	·067880	14·73167	·9977040	7
13	·0561119	·056200	17·79344	·9984245	47	34	·0622099	·062330	16·04348	·9980631	26	54	·0680153	·068173	14·66852	·9976843	6
14	·0564024	·056492	17·70152	·9984081	46	35	·0625002	·062622	15·96866	·9980450	25	55	·0683055	·068465	14·60591	·9976645	5
15	·0566928	·056784	17·61055	·9983917	45	36	·0627905	·062914	15·89454	·9980267	24	56	·0685957	·068757	14·54383	·9976445	4
16	·0569832	·057075	17·52051	·9983751	44	37	·0630808	·063206	15·82110	·9980084	22	57	·0688859	·069049	14·48227	·9976245	3
17	·0572736	·057367	17·43139	·9983585	43	38	·0633711	·063498	15·74833	·9979900	22	58	·0691761	·069342	14·42123	·9976045	2
18	·0575640	·057659	17·34315	·9983418	42	39	·0636614	·063790	15·67623	·9979716	21	59	·0694663	·069634	14·36069	·9975843	1
19	·0578544	·057951	17·25580	·9983250	41	40	·0639517	·064082	15·60478	·9979530	20	60	·0697565	·069926	14·30066	·9975641	0
20	·0581448	·058243	17·16933	·9983082	40											J.B.R.	
′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 86 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 86 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Table No. 60.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

Dep. 4 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 4 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·0697565	·069926	14·30066	·9975641	60	21	·0758489	·076068	13·14612	·9971193	39	41	·0816486	·081922	12·20671	·9966612	19
1	·0700467	·070219	14·24113	·9975437	59	22	·0761390	·076360	13·09575	·9970972	38	42	·0819385	·082215	12·16323	·9966374	18
2	·0703368	·070511	14·18209	·9975233	58	23	·0764290	·076653	13.04576	·9970760	37	43	·0822284	·082507	12·12006	·9966135	17
3	·0706270	·070803	14·12353	·9975028	57	24	·0767190	·076945	12·99616	·9970528	36	44	·0825183	·082800	12·07719	·9965895	16
4	·0709171	·071096	14·06545	·9974822	56	25	·0770091	·077238	12·94692	·9970304	35	45	·0828082	·083093	12·03462	·9965655	15
5	·0712073	·071388	14·00785	·9974615	55	26	·0772991	·077531	12·89805	·9970080	34	46	·0830981	·083386	11·99234	·9965414	14
6	·0714974	·071680	13·95071	·9974408	54	27	·0775891	·077823	12·84955	·9969854	33	47	·0833880	·083679	11·95037	·9965172	13
7	·0717876	·071973	13·89404	·9974199	53	28	·0778791	·078116	12·80141	·9969628	32	48	·0836778	·083972	11·90868	·9964929	12
8	·0720777	·072265	13·83782	·9973990	52	29	·0781691	·078409	12·75363	·9969401	31	49	·0839677	·084265	11·86728	·9964685	11
9	·0723678	·072558	13·78206	·9973780	51	30	·0784591	·078701	12·70620	·9969173	30	50	·0842576	·084558	11·82616	·9964440	10
10	·0726580	·072850	13·72673	·9973569	50	31	·0787491	·078994	12·65912	·9968945	29	51	·0845474	·084851	11·78533	·9964195	9
11	·0729481	·073143	13·67185	·9973357	49	32	·0790391	·079287	12·61239	·9968715	28	52	·0848373	·085144	11·74477	·9963948	8
12	·0732382	·073435	13·61740	·9973145	48	33	·0793290	·079579	12·56599	·9968485	27	53	·0851271	·085437	11·70450	·9963701	7
13	·0735283	·073727	13·56339	·9972931	47	34	·0796190	·079872	12·51994	·9968254	26	54	·0854169	·085730	11·66449	·9963453	6
14	·0738184	·074020	13·50979	·9972717	46	35	·0799090	.080165	12·47422	·9968022	25	55	·0857067	·086023	11·62176	·9963204	5
15	·0741085	·074312	13·45662	·9972502	45	36	·0801989	·080458	12·42883	·9967789	24	56	·0859966	·086316	11·58529	·9962954	4
16	·0743986	·074605	13·40386	·9972286	44	37	·0804889	·080750	12·38376	·9967555	23	57	·0862864	·086609	11·54609	·9962704	3
17	·0746887	·074897	13·35151	·9972069	43	38	·0807788	·081043	12·33902	·9967321	22	58	·0865762	·086902	11·50715	·9962452	2
18	·0749787	·075190	13·29957	·9971851	42	39	·0810687	·081336	12·29460	·9967085	21	59	·0868660	·087195	11·46847	·9962200	1
19	·0752688	·075482	13·24803	·9971633	41	40	·0813587	·081629	12·25050	·9966849	20	60	·0871557	·087488	11·43005	·9961947	0
20	·0755589	·075775	13·19688	·9971413	40												
′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 85 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 85 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Table No. 63.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

'	Sine	Tang	Cotang	Cosine	'
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	44
17	·0990800	·0992479	10·81387	·9957515	43
18	·0993706	·0992707	10·77907	·9957247	42
19	·0996602	·0993000	10·74508	·9956978	41
20	·0999498	·0993354	10·71101	·9956708	40
'	Cosine.	Cotan.	Tang.	Sine.	'

'	Sine	Tang	Cotang	Cosine	'
21	[illegible]	[illegible]	[illegible]	[illegible]	39
22	[illegible]	[illegible]	[illegible]	[illegible]	38
23	[illegible]	[illegible]	[illegible]	[illegible]	37
24	[illegible]	[illegible]	[illegible]	[illegible]	36
25	[illegible]	[illegible]	[illegible]	[illegible]	35
26	[illegible]	[illegible]	[illegible]	[illegible]	34
27	[illegible]	[illegible]	10·48126	·9954794	33
28	[illegible]	[illegible]	10·44911	·9954517	32
29	[illegible]	[illegible]	10·41716	·9954240	31
30	[illegible]	[illegible]	10·38539	·9953962	30
31	[illegible]	[illegible]	10·35382	·9953683	29
32	[illegible]	·0986476	10·32244	·9953403	28
33	[illegible]	·0987180	10·29128	·9953122	27
34	[illegible]	·0987463	10·26021	·9952840	26
35	·0972914	·0987767	10·22948	·9952557	25
36	·0975820	·0988050	10·19878	·9952274	24
37	·0978734	·0988344	10·16833	·9951990	23
38	·0981619	·0988638	10·13805	·9951705	22
39	·0984511	·0988932	10·10795	·9951419	21
40	·0987408	·0989225	10·07803	·9951132	20
'	Cosine.	Cotan.	Tang.	Sine.	'

'	Sine	Tang	Cotang	Cosine	'
41	[illegible]	[illegible]	10·04828	·9950814	19
42	[illegible]	[illegible]	10·01871	·9950558	18
43	[illegible]	·100107	9·980305	·9950266	17
44	[illegible]	·100400	9·960072	·9949970	16
45	·1001281	·100694	9·931008	·9949685	15
46	·1004775	·100988	9·902112	·9949393	14
47	·1007669	·101282	9·873382	·9949101	13
48	·1010563	·101576	9·844816	·9948807	12
49	·1013457	·101870	9·816414	·9948513	11
50	·1016351	·102164	9·788173	·9948217	10
51	·1019245	·102458	9·760092	·9947921	9
52	·1022138	·102752	9·732171	·9947625	8
53	·1025032	·103046	9·704407	·9947327	7
54	·1027925	·103339	9·676800	·9947028	6
55	·1030819	·103634	9·649347	·9946729	5
56	·1033712	·103928	9·622048	·9946428	4
57	·1036605	·104222	9·594902	·9946127	3
58	·1039499	·104516	9·567906	·9945825	2
59	·1042392	·104810	9·541061	·9945523	1
60	·1045285	·105104	9·514364	·9945219	0
'	Cosine.	Cotan.	Tang.	Sine.	'

Table No. 62.

RAVERSE TABLE FOR A DISTANCE = 1.

ude — Cosine. Departure — Sine.

'	Cosine.	Cotan.	Tang.	Sine.	'	'	Cosine.	Cotan.	Tang.	Sine.	'	'	Cosine.	Cotan.	Tang.	Sine.	'
0	·1045285	·105104	9·514364	·9945219	60	21	·1106017	·111284	8·985984	·9938648	39	41	·1163818	·117178	8·534017	·9932045	19
1	·1048178	·105398	9·487814	·9944914	59	22	·1108908	·111578	8·962266	·9938326	38	42	·1166707	·117473	8·512594	·9931706	18
2	·1051070	·105692	9·461411	·9944609	58	23	·1111799	·111873	8·938672	·9938003	37	43	·1169596	·117767	8·491277	·9931367	17
3	·1053963	·105986	9·435158	·9944303	57	24	·1114689	·112168	8·915200	·9937679	36	44	·1172485	·118062	8·470065	·9931026	16
4	·1056856	·106280	9·409038	·9943996	56	25	·1117580	·112462	8·891850	·9937355	35	45	·1175374	·118357	8·448957	·9930685	15
5	·1059748	·106575	9·383066	·9943688	55	26	·1120471	·112757	8·868620	·9937029	34	46	·1178263	·118652	8·427953	·9930342	14
6	·1062641	·106869	9·357235	·9943379	54	27	·1123361	·113051	8·845510	·9936703	33	47	·1181151	·118947	8·407051	·9929999	13
7	·1065533	·107163	9·331545	·9943070	53	28	·1126252	·113346	8·822518	·9936375	32	48	·1184040	·119242	8·386251	·9929655	12
8	·1068425	·107457	9·305993	·9942760	52	29	·1129142	·113641	8·799644	·9936047	31	49	·1186928	·119537	8·365553	·9929310	11
9	·1071318	·107751	9·280580	·9942449	51	30	·1132032	·113935	8·776887	·9935719	30	50	·1189816	·119832	8·344955	·9928965	10
10	·1074210	·108046	9·255303	·9942136	50	31	·1134922	·114230	8·754246	·9935389	29	51	·1192704	·120127	8·324457	·9928618	9
11	·1077102	·108340	9·230162	·9941823	49	32	·1137812	·114525	8·731719	·9935058	28	52	·1195593	·120423	8·304058	·9928271	8
12	·1079994	·108634	9·205156	·9941510	48	33	·1140702	·114819	8·709307	·9934727	27	53	·1198481	·120718	8·283757	·9927922	7
13	·1082885	·108929	9·180283	·9941195	47	34	·1143592	·115114	8·687008	·9934395	26	54	·1201368	·121013	8·263554	·9927573	6
14	·1085777	·109223	9·155543	·9940880	46	35	·1146482	·115409	8·664822	·9934062	25	55	·1204256	·121308	8·243448	·9927224	5
15	·1088669	·109517	9·130934	·9940563	45	36	·1149372	·115703	8·642747	·9933728	24	56	·1207144	·121603	8·223468	·9926873	4
16	·1091560	·109812	9·106456	·9940246	44	37	·1152261	·115998	8·620783	·9933393	23	57	·1210031	·121898	8·203523	·9926521	3
17	·1094452	·110106	9·082107	·9939928	43	38	·1155151	·116293	8·598929	·9933057	22	58	·1212919	·122194	8·183704	·9926169	2
18	·1097343	·110401	9·057886	·9939610	42	39	·1158040	·116588	8·577183	·9932721	21	59	·1215806	·122489	8·163978	·9925816	1
19	·1100234	·110695	9·033793	·9939290	41	40	·1160929	·116883	8·555546	·9932384	20	60	·1218693	·122784	8·144346	·9925462	0
20	·1103126	·110989	9·009826	·9938969	40											J.B.R.	

Lat. 83 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 83 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
he combined arrangement of tables is original.)

Table No. 63.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS = 1

Dep. 7 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 7 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·1218693	·122784	8·144346	·9925462	60	21	·1279302	·128990	7·752636	·9917832	39	41	·1336979	·134909	7·412397	·9910221	19
1	·1221581	·123079	8·124807	·9925107	59	22	·1282186	·129285	7·734802	·9917459	38	42	·1339862	·135205	7·396159	·9909832	18
2	·1224469	·123375	8·105359	·9924751	58	23	·1285071	·129581	7·717148	·9917086	37	43	·1342744	·135501	7·379990	·9909442	17
3	·1227355	·123670	8·086004	·9924394	57	24	·1287956	·129877	7·699573	·9916712	36	44	·1345627	·135797	7·363891	·9909051	16
4	·1230241	·123965	8·066739	·9924037	56	25	·1290841	·130173	7·682076	·9916337	35	45	·1348509	·136094	7·347861	·9908659	15
5	·1233128	·124261	8·047564	·9923679	55	26	·1293725	·130469	7·664658	·9915961	34	46	·1351392	·136390	7·331898	·9908266	14
6	·1236015	·124556	8·028479	·9923319	54	27	·1296609	·130764	7·647317	·9915584	33	47	·1354274	·136686	7·316004	·9907873	13
7	·1238901	·124852	8·009483	·9922959	53	28	·1299494	·131060	7·630053	·9915206	32	48	·1357156	·136983	7·300178	·9907478	12
8	·1241788	·125147	7 990575	·9922599	52	29	·1302378	·131356	7·612865	·9914828	31	49	·1360038	·137279	7·284418	·9907083	11
9	·1244674	·125442	7·971755	·9922237	51	30	·1305262	·131652	7·595754	·9914449	30	50	·1362919	·137575	7·268725	·9906657	10
10	·1247560	·125738	7·953022	·9921874	50	31	·1308146	·131948	7·578717	·9914069	29	51	·1365801	·137872	7·253098	·9906260	9
11	·1250446	·126033	7·934375	·9921511	49	32	·1311030	·132244	7·561756	·9913688	28	52	·1368683	·138168	7·237537	·9905893	8
12	·1253332	·126329	7·915815	·9921147	48	33	·1313913	·132540	7·544869	·9913306	27	53	·1371564	·138465	7·222042	·9905494	7
13	·1256218	·126624	7·897339	·9920782	47	34	·1316797	·132836	7·528057	·9912923	26	54	·1374445	·138761	7·206611	·9905095	6
14	·1259104	·126920	7·878948	·9920416	46	35	·1319681	·133132	7·511317	·9912540	25	55	·1377327	·139058	7·191245	·9904694	5
15	·1261990	·127216	7·860642	·9920049	45	36	·1322564	·133428	7·494651	·9912155	24	56	·1380208	·139354	7·175943	·9904293	4
16	·1264875	·127511	7·842419	·9919682	44	37	·1325447	·133724	7·478057	·9911770	23	57	·1383089	·139651	7·160705	·9903891	3
17	·1267761	·127807	7·824279	·9919314	43	38	·1328330	·134020	7·461535	·9911384	22	58	·1385970	·139947	7·145530	·9903489	2
18	·1270646	·128103	7·806221	·9918944	42	39	·1331213	·134316	7·445085	·9910997	21	59	·1388850	·140244	7·130419	·9903085	1
19	·1273531	·128398	7·788245	·9918574	41	40	·1334096	·134612	7·428706	·9910610	20	60	·1391731	·140540	7·115369	·9902681	0
20	·1276416	·128694	7·770350	·9918204	40											J.B.R.	
′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′	′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 82 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 82 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Table No. 64.

81°

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude — Cosine. Departure — Sine.

Dep. 8 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 8 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·1391731	·140540	7·115369	·9902681	60
1	·1394612	·140837	7·100382	·9902275	59
2	·1397492	·141134	7·085457	·9901869	58
3	·1400372	·141430	7·070593	·9901462	57
4	·1403252	·141727	7·055790	·9901055	56
5	·1406132	·142024	7·041048	·9900646	55
6	·1409012	·142321	7·026366	·9900237	54
7	·1411892	·142617	7·011744	·9899826	53
8	·1414772	·142914	6·997180	·9899415	52
9	·1417651	·143211	6·982678	·9899003	51
10	·1420531	·143508	6·968233	·9898590	50
11	·1423410	·143805	6·953847	·9898177	49
12	·1426289	·144102	6·939519	·9897762	48
13	·1429168	·144399	6·925248	·9897347	47
14	·1432047	·144696	6·911035	·9896931	46
15	·1434926	·144993	6·896879	·9896514	45
16	·1437805	·145290	6·882780	·9896096	44
17	·1440684	·145587	6·868737	·9895677	43
18	·1443562	·145884	6·854750	·9895258	42
19	·1446440	·146181	6·840819	·9894838	41
20	·1449319	·146478	6·826943	·9894416	40
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·1452197	·146775	6·813122	·9893994	39
22	·1455075	·147072	6·799356	·9893572	38
23	·1457953	·147369	6·785644	·9893148	37
24	·1460830	·147667	6·771986	·9892723	36
25	·1463708	·147964	6·758382	·9892298	35
26	·1466585	·148261	6·744831	·9891872	34
27	·1469463	·148559	6·731334	·9891445	33
28	·1472340	·148856	6·717889	·9891017	32
29	·1475217	·149153	6·704496	·9890588	31
30	·1478094	·149451	6·691156	·9890159	30
31	·1480971	·149748	6·677867	·9889728	29
32	·1483848	·150045	6·664630	·9889297	28
33	·1486724	·150343	6·651444	·9888865	27
34	·1489601	·150640	6·638310	·9888432	26
35	·1492477	·150938	6·625225	·9887998	25
36	·1495353	·151235	6·612191	·9887564	24
37	·1498230	·151533	6·599208	·9887128	23
38	·1501106	·151830	6·586273	·9886692	22
39	·1503981	·152128	6·573389	·9886255	21
40	·1506857	·152426	6·560553	·9885817	20
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·1509733	·152723	6·547767	·9885378	19
42	·1512608	·153021	6·535029	·9884939	18
43	·1515484	·153319	6·522339	·9884498	17
44	·1518359	·153617	6·509698	·9884057	16
45	·1521234	·153914	6·497104	·9883615	15
46	·1524109	·154212	6·484558	·9883172	14
47	·1526984	·154510	6·472059	·9882728	13
48	·1529858	·154808	6·459607	·9882284	12
49	·1532733	·155106	6·447201	·9881838	11
50	·1535607	·155404	6·434842	·9881392	10
51	·1538482	·155701	6·422530	·9880945	9
52	·1541356	·155999	6·410263	·9880497	8
53	·1544230	·156297	6·398042	·9880048	7
54	·1547104	·156595	6·385866	·9879599	6
55	·1549978	·156893	6·373735	·9879148	5
56	·1552851	·157191	6·361650	·9878697	4
57	·1555725	·157490	6·349609	·9878245	3
58	·1558598	·157788	6·337612	·9877792	2
59	·1561472	·158086	6·325660	·9877338	1
60	·1564345	·158384	6·313751	·9876883	0
				J.B.R.	
′	Cosine.	Cotan.	Tang.	Sine.	′

Lat. 81 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 81 DEGREES Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Table No. 65.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Length of Natural Sines, Tangents, Cotangents and Cosines when Radius = 1

Dep. 9 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 9 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·1564345	·158384	6·313751	·9876883	60
1	·1567218	·158682	6·301886	·9876428	59
2	·1570091	·158980	6·290065	·9875972	58
3	·1572963	·159279	6·278286	·9875514	57
4	·1575836	·159577	6·266551	·9875057	56
5	·1578708	·159875	6·254858	·9874598	55
6	·1581581	·160174	6·243208	·9874138	54
7	·1584453	·160472	6·231600	·9873678	53
8	·1587325	·160770	6·220034	·9873216	52
9	·1590197	·161069	6·208510	·9872754	51
10	·1593069	·161367	6·197027	·9872291	50
11	·1595940	·161666	6·185586	·9871827	49
12	·1598812	·161964	6·174186	·9871363	48
13	·1601683	·162263	6·162827	·9870897	47
14	·1604555	·162561	6·151508	·9870431	46
15	·1607426	·162860	6·140230	·9869964	45
16	·1610297	·163159	6·128992	·9869496	44
17	·1613167	·163457	6·117794	·9869027	43
18	·1616038	·163756	6·106636	·9868557	42
19	·1618909	·164055	6·095517	·9868087	41
20	·1621779	·164353	6·084438	·9867615	40
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·1624650	·164652	6·073397	·9867143	39
22	·1627520	·164951	6·062396	·9866670	38
23	·1630390	·165250	6·051434	·9866196	37
24	·1633260	·165548	6·040510	·9865722	36
25	·1636129	·165847	6·029624	·9865246	35
26	·1638999	·166146	6·018777	·9864770	34
27	·1641868	·166445	6·007967	·9864293	33
28	·1644738	·166744	5·997195	·9863815	32
29	·1647607	·167043	5·986461	·9863336	31
30	·1650476	·167342	5·975764	·9862856	30
31	·1653345	·167641	5·965104	·9862375	29
32	·1656214	·167940	5·954481	·9861894	28
33	·1659082	·168239	5·943895	·9861412	27
34	·1661951	·168539	5·933345	·9860929	26
35	·1664819	·168838	5·922832	·9860445	25
36	·1667687	·169137	5·912355	·9859960	24
37	·1670556	·169436	5·901913	·9859475	23
38	·1673423	·169735	5·891508	·9858988	22
39	·1676291	·170035	5·881138	·9858501	21
40	·1679159	·170334	5·870804	·9858013	20
′	Cosine.	Cotan.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·1682026	·170633	5·860505	·9857524	19
42	·1684894	·170933	5·850241	·9857035	18
43	·1687761	·171232	5·840011	·9856544	17
44	·1690628	·171532	5·829817	·9856053	16
45	·1693495	·171831	5·819657	·9855561	15
46	·1696362	·172130	5·809531	·9855068	14
47	·1699228	·172430	5·799440	·9854574	13
48	·1702095	·172730	5·789382	·9854079	12
49	·1704961	·173029	5·779358	·9853583	11
50	·1707828	·173329	5·769368	·9853087	10
51	·1710694	·173628	5·759412	·9852590	9
52	·1713560	·173928	5·749488	·9852092	8
53	·1716425	·174228	5·739598	·9851593	7
54	·1719291	·174527	5·729741	·9851093	6
55	·1722156	·174827	5·719917	·9850593	5
56	·1725022	·175127	5·710125	·9850091	4
57	·1727887	·175427	5·700366	·9849589	3
58	·1730752	·175727	5·690639	·9849086	2
59	·1733617	·176027	5·680944	·9848582	1
60	·1736482	·176327	5·671281	·9848078	0
′	Cosine.	Cotan.	Tang.	Sine.	′

J.R.R.

Lat. 80 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 80 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(The combined arrangement of tables is original.)

Table No. 66.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude — Cosine. Departure — Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS

Dep. 10 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 10 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·1736482	·176327	5·671281	·9848078	60
1	·1739346	·176626	5·661650	·9847572	59
2	·1742211	·176026	5·652051	·9847066	58
3	·1745075	·177226	5·642483	·9846558	57
4	·1747939	·177527	5·632947	·9846050	56
5	·1750803	·177827	5·623442	·9845542	55
6	·1753667	·178127	5·613968	·9845032	54
7	·1756531	·178427	5·604524	·9844521	53
8	·1759395	·178727	5·595112	·9844010	52
9	·1762258	·179027	5·585730	·9843498	51
10	·1765121	·179327	5·576378	·9842985	50
11	·1767984	·179628	5·567057	·9842471	49
12	·1770847	·179928	5·557766	·9841956	48
13	·1773710	·180228	5·548505	·9841441	47
14	·1776573	·180529	5·539274	·9840924	46
15	·1779435	·180829	5·530072	·9840407	45
16	·1782298	·181129	5·520900	·9839889	44
17	·1785160	·181430	5·511757	·9839370	43
18	·1788022	·181730	5·502644	·9838850	42
19	·1790884	·182031	5·493560	·9838330	41
20	·1793746	·182331	5·484505	·9837808	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·1796607	·182632	5·475478	·9837286	39
22	·1799469	·182933	5·466481	·9836763	38
23	·1802330	·183233	5 457512	·9830239	37
24	·1805191	·183534	5·448571	·9835715	36
25	·1808052	·183835	5·439659	·9835189	35
26	·1810913	·184135	5·430775	·9834663	34
27	·1813774	·184436	5·421918	·9834136	33
28	·1816635	·184737	5·413090	·9833608	32
29	·1819495	·185038	5·404290	·9833079	31
30	·1822355	·185339	5·395517	·9832549	30
31	·1825215	·185639	5·386771	·9832019	29
32	·1828075	·185940	5·379053	·9831487	28
33	·1830935	·186241	5·369363	·9830955	27
34	·1833795	·186542	5·360699	·9830422	26
35	·1836654	·186843	5·352062	·9829888	25
36	·1839514	·187144	5·343452	·9829353	24
37	·1842373	·187446	5·334869	·9828818	23
38	·1845232	·187747	5·326313	·9828282	22
39	·1848091	·188048	5·317783	·9827744	21
40	·1950949	·188349	5·309279	·9827206	20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·1853808	·188650	5·300801	·9826668	19
42	·1856666	·188952	5·292350	·9826128	18
43	·1859524	·189253	5·283925	·9825587	17
44	·1862382	·189554	5·275525	·9825046	16
45	·1865240	·189855	5·267151	·9824504	15
46	·1868098	·190157	5·258803	·9823961	14
47	·1870956	·190458	5·250480	·9823417	13
48	·1873813	·190760	5·242183	·9822873	12
49	·1876670	·191061	5·233911	·9822327	11
50	·1879528	·191363	5·225664	·9821781	10
51	·1882385	·191664	5·217442	·9821234	9
52	·1885241	·191966	5·209245	·9820686	8
53	·1888098	·192268	5·201073	·9820137	7
54	·1890954	·192569	5·192926	·9819587	6
55	·1893811	·192871	5·184803	·9819037	5
56	·1896667	·193173	5·176705	·9818485	4
57	·1899523	·193474	5·168631	·9817933	3
58	·1902379	·193776	5·160581	·9817380	2
59	·1905234	·194078	5·152555	·9816826	1
60	·1908090	·194380	5·144554	·9816272	0
′	Cosine.	Cotang.	Tang.	Sine.	′

J.B.R.

Lat. 79 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 79 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(*The combined arrangement of tables is original.*)

Table No. 67.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = S[ine]

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=

Dep. 11 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 11 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·1908090	·194380	5·144554	·9816272	60	21	·1968018	·200727	4·981881	·9804433	39	41	·2025024	·206786	4·835901	·9792818	19
1	·1910945	·194682	5·136576	·9815716	59	22	·1970870	·201030	4·974381	·9803860	38	42	·2027873	·207090	4·828817	·9792228	18
2	·1913801	·194984	5·128622	·9815160	58	23	·1973722	·201332	4·966903	·9803286	37	43	·2030721	·207393	4·821753	·9791638	17
3	·1916656	·195286	5·120692	·9814603	57	24	·1976573	·201635	4·959447	·9802712	36	44	·2033569	·207696	4·814709	·9791047	16
4	·1919510	·195588	5·112785	·9814045	56	25	·1979425	·201938	4·952012	·9802136	35	45	·2036418	·208000	4·807685	·9790455	15
5	·1922365	·195890	5·104902	·9813486	55	26	·1982276	·202240	4·944599	·9801560	34	46	·2039265	·208303	4·800680	·9789862	14
6	·1925220	·196192	5·097042	·9812927	54	27	·1985127	·202543	4·937206	·9800983	33	47	·2042113	·208607	4·793695	·9789268	13
7	·1928074	·196494	5·089206	·9812366	53	28	·1987978	·202846	4·929835	·9800405	32	48	·2044961	·208910	4·786730	·9788674	12
8	·1930928	·196796	5·081392	·9811805	52	29	·1990829	·203149	4·922485	·9799827	31	49	·2047808	·209214	4·779783	·9788079	11
9	·1933782	·197098	5·073602	·9811243	51	30	·1993679	·203452	4·915157	·9799247	30	50	·2050655	·209518	4·772856	·9787483	10
10	·1936636	·197400	5·065835	·9810680	50	31	·1996530	·203755	4·907849	·9798667	29	51	·2053502	·209821	4·765949	·9786886	9
11	·1939490	·197703	5·058090	·9810116	49	32	·1999380	·204058	4·900562	·9798086	28	52	·2056349	·210125	4·759060	·9786288	8
12	·1942344	·198005	5·050369	·9809552	48	33	·2002230	·204361	4·893295	·9797504	27	53	·2059195	·210429	4·752190	·9785689	7
13	·1945197	·198307	5·042670	·9808986	47	34	·2005080	·204664	4·886049	·9796921	26	54	·2062042	·210733	4·745340	·9785090	6
14	·1948050	·198610	5·034993	·9808420	46	35	·2007930	·204967	4·878824	·9796337	25	55	·2064888	·211036	4·738508	·9784490	5
15	·1950903	·198912	5·027339	·9807853	45	36	·2010779	·205270	4·871620	·9795752	24	56	·2067734	·211340	4·731695	·9783889	4
16	·1953756	·199214	5·019707	·9807285	44	37	·2013629	·205573	4·864435	·9795167	23	57	·2070580	·211644	4·724901	·9783287	3
17	·1956609	·199517	5·012098	·9806716	43	38	·2016478	·205876	4·857271	·9794581	22	58	·2073426	·211948	4·718125	·9782684	2
18	·1959461	·199819	5·004511	·9806147	42	39	·2019327	·206180	4·850128	·9793994	21	59	·2076272	·212252	4·711368	·9782080	1
19	·1962314	·200122	4·996945	·9805576	41	40	·2022176	·206483	4·843004	·9793406	20	60	·2079117	·212556	4·704630	·9781476	0
20	·1965166	·200424	4·989402	·9805005	40												

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(The combined arrangement of tables is origin[al]

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS = 1

Dep. 12 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 12 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·2079117	·212556	4·704630	·9781476	60
1	·2081962	·212860	4·697910	·9780871	59
2	·2084807	·213164	4·691208	·9780265	58
3	·2087652	·213468	4·684524	·9779658	57
4	·2090497	·213773	4·677859	·9779050	56
5	·2093341	·214077	4·671212	·9778441	55
6	·2096186	·214381	4·664583	·9777832	54
7	·2099030	·214685	4·657972	·9777222	53
8	·2101874	·214990	4·651378	·9776611	52
9	·2104718	·215294	4·644803	·9775999	51
10	·2107561	·215598	4·638245	·9775386	50
11	·2110405	·215903	4·631705	·9774779	49
12	·2113248	·216207	4·625183	·9774159	48
13	·2116091	·216512	4·618678	·9773544	47
14	·2118934	·216816	4·612190	·9772928	46
15	·2121777	·217121	4·605720	·9772311	45
16	·2124619	·217425	4·599268	·9771693	44
17	·2127462	·217730	4·592832	·9771075	43
18	·2130304	·218035	4·586414	·9770456	42
19	·2133146	·218340	4·580012	·9769836	41
20	·2135988	·218644	4·573628	·9769215	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·2138829	·218949	4·567261	·9768593	39
22	·2141671	·219254	4·560911	·9767970	38
23	·2144512	·219559	4·554577	·9767347	37
24	·2147353	·219864	4·548260	·9766723	36
25	·2150194	·220169	4·541960	·9766098	35
26	·2153035	·220474	4·535677	·9765472	34
27	·2155876	·220779	4·529410	·9764845	33
28	·2158716	·221084	4·523160	·9764217	32
29	·2161556	·221389	4·516926	·9763589	31
30	·2164396	·221694	4·510708	·9762960	30
31	·2167236	·221999	4·504507	·9762330	29
32	·2170076	·222305	4·498322	·9761699	28
33	·2172915	·222610	4·492153	·9761067	27
34	·2175754	·222915	4·486000	·9760435	26
35	·2178593	·223221	4·479863	·9759802	25
36	·2181432	·223526	4·473742	·9759168	24
37	·2184271	·223831	4·467637	·9758533	23
38	·2187110	·224137	4·461548	·9757897	22
39	·2189948	·224442	4·455475	·9757260	21
40	·2192786	·224748	4·449418	·9756623	20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·2195624	·225054	4·443376	·9755985	19
42	·2198462	·225359	4·437350	·9755345	18
43	·2201300	·225665	4·431339	·9754706	17
44	·2204137	·225971	4·425343	·9754065	16
45	·2206974	·226276	4·419364	·9753423	15
46	·2209811	·226582	4·413399	·9752781	14
47	·2212648	·226888	4·407450	·9752138	13
48	·2215485	·227194	4·401516	·9751494	12
49	·2218321	·227500	4·395597	·9750849	11
50	·2221158	·227806	4·389694	·9750203	10
51	·2223994	·228112	4·383805	·9749556	9
52	·2226830	·228418	4·377931	·9748909	8
53	·2229666	·228724	4·372073	·9748261	7
54	·2232501	·229030	4·366229	·9747612	6
55	·2235337	·229336	4·360100	·9746962	5
56	·2238172	·229642	4·354586	·9746311	4
57	·2241007	·229949	4·348786	·9745660	3
58	·2243842	·230255	4·343001	·9745008	2
59	·2246676	·230561	4·337231	·9744355	1
60	·2249511	·230868	4·331475	·9743701	0
				J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 77 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 77 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Table No. 28

Traverse Tables — Distance = 1.

Latitude = Cosine. Departure = Sine.

′	Sine	Tang	Cotang	Cosine	′	′	Sine	Tang	Cotang	Cosine	′	′	Sine	Tang	Cotang	Cosine	′
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	·2306159	·237004	4·219331	·9730449	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
The combined arrangement of tables is original [illegible]

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 14 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 14 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·2419219	·249328	4·010780	·9702957	60	21	·2478445	·255826	3·908901	·9687998	39	41	·2534766	·262034	3·816295	·9673415	19
1	·2422041	·249637	4·005816	·9702253	59	22	·2481263	·256136	3·904171	·9687277	38	42	·2537579	·262345	3·811773	·9672678	18
2	·2424863	·249946	4·000863	·9701548	58	23	·2484081	·256446	3·899451	·9686555	37	43	·2540393	·262656	3·807260	·9671939	17
3	·2427685	·250255	3·995922	·9700842	57	24	·2486899	·256756	3·894742	·9685832	36	44	·2543206	·262967	3·802758	·9671200	16
4	·2430507	·250564	3·990992	·9700135	56	25	·2489716	·257066	3·890044	·9685108	35	45	·2546019	·263278	3·798266	·9670459	15
5	·2433329	·250873	3·986073	·9699428	55	26	·2492533	·257376	3·885357	·9684383	34	46	·2548832	·263589	3·793783	·9669718	14
6	·2436150	·251182	3·981166	·9698720	54	27	·2495350	·257686	3·880680	·9683658	33	47	·2551645	·263900	3·789310	·9668977	13
7	·2438971	·251491	3·976271	·9698011	53	28	·2498167	·257997	3·876014	·9682931	32	48	·2554458	·264211	3·784848	·9668234	12
8	·2441792	·251801	3·971386	·9697301	52	29	·2500984	·258307	3·871358	·9682204	31	49	·2557270	·264522	3·780395	·9667490	11
9	·2444613	·252110	3·966513	·9696591	51	30	·2503800	·258617	3·866713	·9681476	30	50	·2560082	·264833	3·775951	·9666746	10
10	·2447433	·252420	3·961651	·9695879	50	31	·2506616	·258928	3·862078	·9680748	29	51	·2562894	·265145	3·771518	·9666001	9
11	·2450254	·252729	3·956801	·9695167	49	32	·2509432	·259238	3·857453	·9680018	28	52	·2565705	·265456	3·767094	·9665255	8
12	·2453074	·253038	3·951961	·9694453	48	33	·2512248	·259548	3·852839	·9679288	27	53	·2568517	·265768	3·762680	·9664508	7
13	·2455894	·253348	3·947133	·9693740	47	34	·2515063	·259859	3·848235	·9678557	26	54	·2571328	·266079	3·758276	·9663761	6
14	·2458713	·253658	3·942315	·9693025	46	35	·2517879	·260169	3·843642	·9677825	25	55	·2574139	·266390	3·753881	·9663012	5
15	·2461533	·253967	3·937509	·9692309	45	36	·2520694	·260480	3·839059	·9677092	24	56	·2576950	·266702	3·749496	·9662263	4
16	·2464352	·254277	3·932714	·9691593	44	37	·2523508	·260791	3·834486	·9676358	23	57	·2579760	·267014	3·745120	·9661513	3
17	·2467171	·254587	3·927929	·9690875	43	38	·2526323	·261101	3·829923	·9675624	22	58	·2582570	·267325	3·740754	·9660762	2
18	·2469990	·254896	3·923156	·9690157	42	39	·2529137	·261412	3·825370	·9674888	21	59	·2585381	·267637	3·736398	·9660011	1
19	·2472809	·255206	3·918393	·9689438	41	40	·2531952	·261723	3·820826	·9674152	20	60	·2588190	·267949	3·732050	·9659258	0
20	·2475627	·255516	3·913642	·9688719	40											J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 75 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 75 DEGREES. Dep

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES (RADIUS = 1)

Dep. 15 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 15 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·2588190	·267949	3·732050	·9659258	60	21	·2647147	·274507	3·642891	·9643268	39	41	·2703204	·280770	3·561200	·9627704	19
1	·2591000	·268261	3·727713	·9658505	59	22	·2649952	·274820	3·638744	·9642497	38	42	·2706004	·281087	3·557813	·9626917	18
2	·2593810	·268572	3·723384	·9657751	58	23	·2652757	·275133	3·634606	·9641726	37	43	·2708805	·281401	3·553811	·9626130	17
3	·2596619	·268884	3·719065	·9656996	57	24	·2655561	·275445	3·630477	·9640954	36	44	·2711605	·281716	3·549981	·9625342	16
4	·2599428	·269196	3·714756	·9656240	56	25	·2658366	·275758	3·626356	·9640181	35	45	·2714404	·282030	3·545742	·9624555	15
5	·2602237	·269508	3·710455	·9655484	55	26	·2661170	·276071	3·622244	·9639407	34	46	·2717204	·282344	3·541788	·9623762	14
6	·2605045	·269820	3·706164	·9654726	54	27	·2663973	·276385	3·618141	·9638633	33	47	·2720003	·282657	3·537889	·9622972	13
7	·2607853	·270132	3·701883	·9653968	53	28	·2666777	·276698	3·614046	·9637858	32	48	·2722802	·282971	3·533925	·9622180	12
8	·2610662	·270444	3·697610	·9653209	52	29	·2669581	·277011	3·609960	·9637081	31	49	·2725601	·283286	3·530005	·9621387	11
9	·2613469	·270757	3·693346	·9652449	51	30	·2672384	·277324	3·605883	·9636305	30	50	·2728400	·283599	3·526093	·9620594	10
10	·2616277	·271069	3·689092	·9651689	50	31	·2675187	·277637	3·601814	·9635527	29	51	·2731198	·283914	3·522190	·9619800	9
11	·2619085	·271381	3·684847	·9650927	49	32	·2677989	·277951	3·597754	·9634748	28	52	·2733997	·284228	3·518294	·9619006	8
12	·2621892	·271694	3·680611	·9650165	48	33	·2680792	·278264	3·593702	·9633969	27	53	·2736794	·284543	3·514407	·9618210	7
13	·2624699	·272006	3·676384	·9649102	47	34	·2683594	·278578	3·589659	·9633189	26	54	·2739592	·284857	3·510527	·9617413	6
14	·2627506	·272318	3·672166	·9648638	46	35	·2686396	·278891	3·585624	·9632408	25	55	·2742390	·285172	3·506655	·9616616	5
15	·2630312	·272631	3·667957	·9647873	45	36	·2689198	·279205	3·581597	·9631626	24	56	·2745187	·285486	3·502791	·9615818	4
16	·2633118	·272943	3·663757	·9647108	44	37	·2692000	·279518	3·577579	·9630843	23	57	·2747984	·285801	3·498935	·9615019	3
17	·2635925	·273256	3·659566	·9646341	43	38	·2694801	·279832	3·573569	·9630060	22	58	·2750781	·286115	3·495087	·9614219	2
18	·2638730	·273569	3·655384	·9645574	42	39	·2697602	·280145	3·569568	·9629275	21	59	·2753577	·286430	3·491247	·9613418	1
19	·2641536	·273881	3·651211	·9644806	41	40	·2700403	·280459	3·565574	·9628490	20	60	·2756374	·286745	3·487414	·9612617	0
20	·2644342	·274194	3·647046	·9644037	40											J.B.B.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 74 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 74 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(combined arrangement of tables is original.)

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Length of Natural Sines, Tangents, Cotangents and Cosines when Radius=1

Dep. 16 DEGREES. Lat. | Dep. (Read down.) Lat. | Dep. 16 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·2756374	·286745	3·487414	·9612617	60	21	·2815012	·293368	3·408688	·9595600	39	41	·2870819	·299697	3·336609	·9579060	19
1	·2759170	·287060	3·483589	·9611815	59	22	·2817833	·293683	3·405021	·9594781	38	42	·2873605	·300014	3·333173	·9578225	18
2	·2761965	·287375	3·479772	·9611012	58	23	·2820624	·293999	3·401361	·9593961	37	43	·2876391	·300331	3·329654	·9577389	17
3	·2764761	·287690	3·475963	·9610208	57	24	·2823415	·294316	3·397708	·9593140	36	44	·2879177	·300648	3·326141	·9576552	16
4	·2767556	·288005	3·472161	·9609403	56	25	·2826205	·294632	3·394063	·9592318	35	45	·2881963	·300965	3·322636	·9575714	15
5	·2770352	·288320	3·468367	·9608598	55	26	·2828995	·294948	3·390424	·9591496	34	46	·2884748	·301283	3·319137	·9574875	14
6	·2773147	·288635	3·464581	·9607792	54	27	·2831785	·295264	3·386793	·9590672	33	47	·2887533	·301600	3·315645	·9574035	13
7	·2775941	·288950	3·460802	·9606984	53	28	·2834575	·295580	3·383169	·9589848	32	48	·2890318	·301917	3·312159	·9573195	12
8	·2778736	·289265	3·457031	·9606177	52	29	·2837364	·295897	3·379553	·9589023	31	49	·2893103	·302235	3·308681	·9572354	11
9	·2781530	·289580	3·453267	·9605368	51	30	·2840153	·296213	3·375943	·9588197	30	50	·2895887	·302552	3·305209	·9571512	10
10	·2784324	·289896	3·449512	·9604558	50	31	·2842942	·296529	3·372340	·9587371	29	51	·2898671	·302870	3·301743	·9570669	9
11	·2787118	·290211	3·445763	·9603748	49	32	·2845731	·296846	3·368745	·9586513	28	52	·2901455	·303187	3·298285	·9569825	8
12	·2789911	·290526	3·442022	·9602937	48	33	·2848520	·297163	3·365156	·9585715	27	53	·2904239	·303505	3·294833	·9568981	7
13	·2792704	·290842	3·438289	·9602125	47	34	·2851308	·297479	3·361575	·9584886	26	54	·2907022	·303823	3·291387	·9568136	6
14	·2795497	·291157	3·434563	·9601312	46	35	·2854096	·297796	3·358000	·9584056	25	55	·2909805	·304141	3·287948	·9567290	5
15	·2798290	·291473	3·430844	·9600499	45	36	·2856884	·298112	3·354433	·9583226	24	56	·2912588	·304458	3·284516	·9566443	4
16	·2801083	·291789	3·427133	·9599684	44	37	·2859671	·298429	3·350872	·9582394	23	57	·2915371	·304776	3·281090	·9565595	3
17	·2803875	·292104	3·423429	·9598869	43	38	·2862458	·298746	3·347319	·9581562	22	58	·2918153	·305094	3·277671	·9564747	2
18	·2806667	·292420	3·419733	·9598053	42	39	·2865246	·299063	3·343772	·9580729	21	59	·2920935	·305412	3·274258	·9563898	1
19	·2809459	·292736	3·416044	·9597236	41	40	·2868032	·299380	3·340232	·9579895	20	60	·2923717	·305730	3·270852	·9563048	0
20	·2812251	·293052	3·412362	·9596418	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 73 DEGREES. Dep. | Lat. (Read up.) Dep. | Lat. 73 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Table No. 73.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS = 1

Dep. 17 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 17 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·2923717	·305730	3·270852	·9563048	60	21	·2982079	·312422	3·200789	·9545009	39	41	·3037559	·318820	3·136563	·9527499	19
1	·2926499	·306048	3·267452	·9562197	59	22	·2984856	·312742	3·197521	·9544141	38	42	·3040331	·319140	3·133414	·9526615	18
2	·2929280	·306367	3·264059	·9561345	58	23	·2987632	·313061	3·194259	·9543273	37	43	·3043102	·319461	3·130270	·9525730	17
3	·2932061	·306685	3·260672	·9560492	57	24	·2990408	·313381	3·191003	·9542403	36	44	·3045872	·319781	3·127131	·9524844	16
4	·2934842	·307003	3·257292	·9559639	56	25	·2993184	·313700	3·187754	·9541533	35	45	·3048643	·320102	3·123999	·9523958	15
5	·2937623	·307321	3·253918	·9558785	55	26	·2995959	·314020	3·184510	·9540662	34	46	·3051413	·320423	3·120872	·9523071	14
6	·2940403	·307640	3·250550	·9557930	54	27	·2998734	·314339	3·181272	·9539790	33	47	·3054183	·320744	3·117750	·9522183	13
7	·2943183	·307958	3·247189	·9557074	53	28	·3001509	·314659	3·178040	·9538917	32	48	·3056953	·321064	3·114635	·9521294	12
8	·2945963	·308277	3·243834	·9556218	52	29	·3004284	·314979	3·174814	·9538044	31	49	·3059723	·321385	3·111525	·9520404	11
9	·2948743	·308595	3·240486	·9555361	51	30	·3007058	·315298	3·171594	·9537170	30	50	·3062492	·321706	3·108421	·9519514	10
10	·2951522	·308914	3·237143	·9554502	50	31	·3009832	·315618	3·168380	·9536294	29	51	·3065261	·322027	3·105322	·9518623	9
11	·2954302	·309233	3·233807	·9553643	49	32	·3012606	·315938	3·165172	·9535418	28	52	·3068030	·322348	3·102229	·9517731	8
12	·2957081	·309551	3·230478	·9552784	48	33	·3015380	·316258	3·161970	·9534542	27	53	·3070798	·322670	3·099141	·9516838	7
13	·2959859	·309870	3·227154	·9551923	47	34	·3018153	·316578	3·158774	·9533664	26	54	·3073566	·322991	3·096059	·9515944	6
14	·2962638	·310189	3·223837	·9551062	46	35	·3020926	·316898	3·155584	·9532786	25	55	·3076334	·323312	3·092983	·9515050	5
15	·2965416	·310508	3·220526	·9550199	45	36	·3023699	·317218	3·152399	·9531907	24	56	·3079102	·323633	3·089912	·9514154	4
16	·2968194	·310827	3·217221	·9549336	44	37	·3026471	·317538	3·149220	·9531027	23	57	·3081869	·323955	3·086846	·9513258	3
17	·2970971	·311146	3·213922	·9548473	43	38	·3029244	·317859	3·146047	·9530146	22	58	·3084636	·324276	3·083786	·9512361	2
18	·2973749	·311465	3·210630	·9547608	42	39	·3032016	·318179	3·142880	·9529264	21	59	·3087403	·324598	3·080732	·9511464	1
19	·2976526	·311784	3·207344	·9546743	41	40	·3034788	·318499	3·139719	·9528382	20	60	·3090170	·324919	3·077683	·9510565	0
20	·2979303	·312103	3·204063	·9545876	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 72 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 72 DEGREES. Dep.

…parture (Dep.)= Distance east or west.
…ude (Lat.)= Distance north or south.
…bined arrangement of tables is original.)

Table No. 74.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Dep. 18 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 18 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·3090170	·324919	3·077683	·9510565	60
1	·3092936	·325241	3·074640	·9509666	59
2	·3095702	·325563	3·071602	·9508766	58
3	·3098468	·325884	3·068569	·9507865	57
4	·3101234	·326206	3·065542	·9506963	56
5	·3103999	·326528	3·062520	·9506061	55
6	·3106764	·326850	3·059503	·9505157	54
7	·3109529	·327172	3·056492	·9504253	53
8	·3112294	·327494	3·053487	·9503348	52
9	·3115058	·327816	3·050486	·9502443	51
10	·3117822	·328138	3·047491	·9501536	50
11	·3120586	·328461	3·044501	·9500629	49
12	·3123349	·328783	3·041517	·9499721	48
13	·3126112	·329105	3·038538	·9498812	47
14	·3128875	·329428	3·035564	·9497902	46
15	·3131638	·329750	3·032595	·9496991	45
16	·3134400	·330073	3·029632	·9496080	44
17	·3137163	·330395	3·026673	·9495168	43
18	·3139925	·330718	3·023720	·9494255	42
19	·3142686	·331041	3·020772	·9493341	41
20	·3145448	·331363	3·017830	·9492426	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·3148209	·331686	3·014892	·9491511	39
22	·3150969	·332009	3·011960	·9490595	38
23	·3153730	·332332	3·009033	·9489678	37
24	·3156490	·332655	3·006110	·9488760	36
25	·3159250	·332978	3·003193	·9487842	35
26	·3162010	·333302	3·000282	·9486922	34
27	·3164770	·333625	2·997375	·9486002	33
28	·3167529	·333948	2·994473	·9485081	32
29	·3170288	·334271	2·991576	·9484159	31
30	·3173047	·334595	2·988685	·9483237	30
31	·3175805	·334918	2·985798	·9482313	29
32	·3178563	·335242	2·982916	·9481389	28
33	·3181321	·335566	2·980040	·9480464	27
34	·3184079	·335889	2·977168	·9479538	26
35	·3186836	·336213	2·974301	·9478612	25
36	·3189593	·336537	2·971439	·9477684	24
37	·3192350	·336861	2·968583	·9476756	23
38	·3195106	·337185	2·965731	·9475827	22
39	·3197863	·337509	2·962884	·9474897	21
40	·3200619	·337833	2·960042	·9473966	20
′	Cosine	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·3203374	·338157	2·957205	·9473035	19
42	·3206130	·338481	2·954372	·9472103	18
43	·3208885	·338805	2·951545	·9471170	17
44	·3211640	·339129	2·948722	·9470236	16
45	·3214395	·339454	2·945905	·9469301	15
46	·3217149	·339778	2·943092	·9468366	14
47	·3219903	·340103	2·940284	·9467430	13
48	·3222657	·340427	2·937480	·9466493	12
49	·3225411	·340752	2·934682	·9465555	11
50	·3228164	·341077	2·931888	·9464616	10
51	·3230917	·341401	2·929099	·9463677	9
52	·3233670	·341726	2·926315	·9462736	8
53	·3236422	·342051	2·923535	·9461795	7
54	·3239174	·342376	2·920761	·9460854	6
55	·3241926	·342701	2·917990	·9459911	5
56	·3244678	·343026	2·915225	·9458968	4
57	·3247429	·343351	2·912464	·9458023	3
58	·3250180	·343677	2·909708	·9457078	2
59	·3252931	·344002	2·906957	·9456132	1
60	·3255682	·344327	2·904210	·9455186	0
′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 71 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 71 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Departure = Sine

Dep. 19 DEGREES Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	.3255682	.344327	2.904210	.9455186	60
1	.3258432	.344653	2.901469	.9454239	59
2	.3261182	.344978	2.898731	.9453290	58
3	.3263932	.345304	2.895996	.9452341	57
4	.3266681	.345629	2.893270	.9451391	56
5	.3269430	.345955	2.890546	.9450441	55
6	.3272179	.346281	[illegible]	[illegible]	54
7	.3274928	.346606	[illegible]	[illegible]	53
8	.3277676	.346932	[illegible]	[illegible]	52
9	.3280424	.347258	[illegible]	[illegible]	51
10	.3283172	.347584	[illegible]	[illegible]	50
11	.3285919	.347910	[illegible]	[illegible]	49
12	.3288666	.348236	[illegible]	[illegible]	48
13	.3291413	.348562	[illegible]	[illegible]	47
14	.3294160	.348889	[illegible]	[illegible]	46
15	.3296906	.349215	[illegible]	[illegible]	45
16	.3299653	.349541	[illegible]	[illegible]	44
17	.3302398	.349868	2.858270	.9438971	43
18	.3305144	.350195	2.855561	.9438010	42
19	.3307889	.350521	2.852861	.9437048	41
20	.3310634	.350848	2.850734	.9436085	40
′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 70 DEGREES. Dep.

Lat. (Read up.) Dep.

Lat.} 19 70 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
...e (Lat.)—Distance north or south.
...ed arrangement of tables is original.)

Table No. 76.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

Dep. **20** DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. **20** DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·3420201	·363970	2·747477	·9396926	60	21	·3477540	·370903	2·696118	·9375858	39	41	·3532027	·377536	2·648753	·9355468	19
1	·3422935	·364299	2·744992	·9395931	59	22	·3480267	·371234	2·693714	·9374846	38	42	·3534748	·377868	2·646123	·9354440	18
2	·3425668	·364629	2·742512	·9394935	58	23	·3482994	·371565	2·691314	·9373833	37	43	·3537469	·378201	2·644096	·9353412	17
3	·3428400	·364958	2·740035	·9393938	57	24	·3485720	·371896	2·688919	·9372820	36	44	·3540190	·378533	2·641774	·9352382	16
4	·3431133	·365288	2·737562	·9392940	56	25	·3488447	·372227	2·686526	·9371806	35	45	·3542910	·378866	2·639154	·9351352	15
5	·3433865	·365618	2·735093	·9391942	55	26	·3491173	·372559	2·684138	·9370790	34	46	·3545630	·379198	2·637139	·9350321	14
6	·3436597	·365948	2·732628	·9390943	54	27	·3493898	·372890	2·681753	·9369774	33	47	·3548350	·379531	2·634827	·9349289	13
7	·3439329	·366277	2·730167	·9389943	53	28	·3496624	·373221	2·679372	·9368758	32	48	·3551070	·379864	2·632518	,9348257	12
8	·3442060	·366607	2 727710	·9388942	52	29	·3499349	·373553	2·676995	·9367740	31	49	·3553789	·380197	2·630213	·9347223	11
9	·3444791	·366937	2·725256	·9387940	51	30	·3502074	·373884	2·674621	·9366722	30	50	·3556508	·380530	2·627912	·9346189	10
10	·3447521	·367268	2·722807	·9386938	50	31	·3504798	·374216	2·672251	·9365703	29	51	·3559226	·380863	2·625614	·9345154	9
11	·3450252	·367598	2·720362	·9385934	49	32	·3507523	·374547	2·669885	·9364683	28	52	·3561944	·381196	2·623319	·9344119	8
12	·3452982	·367929	2·717920	·9384930	48	33	.3510246	·374879	2·667522	·9363662	27	53	·3564662	·381529	2·621028	·9343082	7
13	·3455712	·368258	2·715482	·9383925	47	34	·3512970	·375211	2·665163	·9362641	26	54	·3567380	·381862	2·618741	·9342045	6
14	·3458441	·368589	2·713048	·9382920	46	35	·3515693	·375543	2·662808	·9361618	25	55	·3570097	·382196	2·616457	·9341007	5
15	·3461171	·368919	2·710618	·9381913	45	36	·3518416	·375875	2·660456	·9360595	24	56	·3572814	·382529	2·614176	·9339968	4
16	·3463900	·369250	2·708192	·9380906	44	37	·3521139	·376207	2·658108	·9359571	23	57	·3575531	·382863	2·611899	·9338928	3
17	·3466628	·369580	2·705769	·9379898	43	38	·3523862	·376539	2·655764	·9358547	22	58	·3578248	·383196	2·609625	·9337888	2
18	·3469357	·369911	2·703351	·9378889	42	39	·3526584	·376871	2·653423	·9357521	21	59	·3580964	·383530	2·607355	·9336846	1
19	·3472085	·370242	2·700936	·9377880	41	40	·3529306	·377203	2·651086	·9356495	20	60	·3583679	·383864	2·605089	·9335804	0
20	·3474812	·370572	2·698525	·9376869	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. **69** DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. **69** DEGREES. Dep

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(*The combined arrangement of tables is original.*)

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Natural Sines, Tangents, Cotangents and Cosines when Radius 1.

Dep. (Read down.) Lat. Dep. 22 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21	·3640641	·390889	2·558268	·9313739	39	41	·3694765	·397611	[illegible]	[illegible]	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	·3643351	·391224	2·556075	·9312679	38	42	[illegible]	[illegible]	[illegible]	[illegible]	18
[illegible]	[illegible]	[illegible]	[illegible]	·9333718	58	23	·3646059	·391560	2·553885	·9311619	37	43	[illegible]	[illegible]	[illegible]	[illegible]	17
[illegible]	[illegible]	[illegible]	[illegible]	·9332677	57	24	·3648768	·391895	2·551699	·9310558	36	44	[illegible]	[illegible]	[illegible]	[illegible]	16
[illegible]	[illegible]	[illegible]	[illegible]	·9331629	56	25	·3651476	·392231	2·549516	·9309496	35	45	[illegible]	[illegible]	[illegible]	[illegible]	15
[illegible]	[illegible]	[illegible]	[illegible]	·9330582	55	26	·3654184	·392567	2·547335	·9308434	34	46	·3708276	[illegible]	[illegible]	[illegible]	14
[illegible]	[illegible]	[illegible]	[illegible]	·9329535	54	27	·3656891	·392902	2·545159	·9307370	33	47	[illegible]	[illegible]	[illegible]	[illegible]	13
[illegible]	[illegible]	[illegible]	2·589317	·9328488	53	28	·3659599	·393238	2·542985	·9306306	32	48	[illegible]	[illegible]	[illegible]	[illegible]	12
[illegible]	[illegible]	[illegible]	2·587078	·9327439	52	29	·3662306	·393574	2·540815	·9305241	31	49	[illegible]	[illegible]	[illegible]	[illegible]	11
9	[illegible]	[illegible]	2·584842	·9326390	51	30	·3665012	·393910	2·538647	·9304176	30	50	[illegible]	[illegible]	[illegible]	[illegible]	10
[illegible]	[illegible]	·387205	2·582609	·9325340	50	31	·3667719	·394246	2·536483	·9303109	29	51	·3721780	·400984	[illegible]	[illegible]	9
[illegible]	[illegible]	·387539	2·580380	·9324290	49	32	·3670425	·394582	2·534323	·9302043	28	52	·3724479	·401321	[illegible]	[illegible]	8
[illegible]	[illegible]	·387874	2·578153	·9323238	48	33	·3673130	·394918	2·532165	·9300974	27	53	·3727179	·401659	[illegible]	[illegible]	7
[illegible]	[illegible]	·388209	2·575931	·9322186	47	34	·3675836	·395255	2·530011	·9299905	26	54	·3729878	·401997	2·487578	[illegible]	6
14	·3621669	·388543	2·573711	·9321133	46	35	·3678541	·395591	2·527859	·9298835	25	55	·3732577	·402335	[illegible]	[illegible]	5
15	·3624380	·388878	2·571495	·9320079	45	36	·3681246	·395928	2·525711	·9297765	24	56	·3735275	·402673	2·483109	·9278191	4
16	·3627091	·389213	2·569283	·9319024	44	37	·3683950	·396264	2·523566	·9296694	23	57	·3737973	·403011	2·481319	·9276104	3
17	·3629802	·389548	2·567073	·9317969	43	38	·3686654	·396601	2·521424	·9295622	22	58	·3740671	·403349	2·479238	·9274016	2
18	·3632512	·389883	2·564867	·9316912	42	39	·3689358	·396937	2·519286	·9294549	21	59	·3743369	·403687	2·477161	·9272928	1
19	·3635222	·390218	2·562664	·9315855	41	40	·3692061	·397274	2·517150	·9293475	20	60	·3746066	·404026	2·475086	·9271839	0
20	·3637932	·390554	2·560464	·9314797	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 67 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 67 DEGREES. Dep.

(Departure = Distance east or west. Latitude = Distance north or south. [illegible] of values in original.)

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude — Cosine. Departure — Sine.

LENGTH OF NATURAL SINES...

Dep. 22 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 22 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·3746066	·404026	2·475086	·9271839	60	21	·3802634	·411149	2·432204	·9248782	39	41	·3856377	·417967	2·392531	·9226503	19
1	·3748763	·404364	2·473015	·9270748	59	22	·3805324	·411489	2·430193	·9247676	38	42	·3859060	·418309	2·390576	·9225381	18
2	·3751459	·404703	2·470947	·9269658	58	23	·3808014	·411830	2·428186	·9246568	37	43	·3861744	·418650	2·388625	·9224258	17
3	·3754156	·405041	2·468881	·9268566	57	24	·3810704	·412170	2·426181	·9245460	36	44	·3864427	·418992	2·386675	·9223134	16
4	·3756852	·405380	2·466819	·9267474	56	25	·3813393	·412510	2·424180	·9244351	35	45	·3867110	·419334	2·384729	·9222010	15
5	·3759547	·405719	2·464759	·9266380	55	26	·3816082	·412851	2·422181	·9243242	34	46	·3869792	·419676	2·382785	·9220884	14
6	·3762243	·406057	2·462703	·9265286	54	27	·3818770	·413191	2·420185	·9242131	33	47	·3872474	·420019	2·380844	·9219758	13
7	·3764938	·406396	2·460649	·9264192	53	29	·3821459	·413532	2·418191	·9241020	32	48	·3875156	·420361	2·378906	·9218632	12
8	·3767632	·406735	2·458598	·9263096	52	29	·3824147	·413872	2·416201	·9239908	31	49	·3877837	·420703	2·376970	·9217504	11
9	·3770327	·407074	2·456551	·9262000	51	30	·3826834	·414213	2·414213	·9238795	30	50	·3880518	·421046	2·375037	·9216375	10
10	·3773021	·407413	2·454506	·9260902	50	31	·3829522	·414554	2·412228	·9237682	29	51	·3883199	·421388	2·373106	·9215246	9
11	·3775714	·407753	2·452464	·9259805	49	32	·3832209	·414895	2·410246	·9236567	28	52	·3885880	·421731	2·371179	·9214116	8
12	·3778408	·408092	2·450425	·9258706	48	33	·3834895	·415236	2·408267	·9235452	27	53	·3888560	·422073	2·369254	·9212986	7
13	·3781101	·408431	2·448389	·9257606	47	34	·3837582	·415577	2·406290	·9234336	26	54	·3891240	·422416	2·367331	·9211854	6
14	·3783794	·408771	2·446355	·9256506	46	35	·3840268	·415918	2·404316	·9233220	25	55	·3893919	·422759	2·365411	·9210722	5
15	·3786486	·409110	2·444325	·9255405	45	36	·3842953	·416259	2·402345	·9232102	24	56	·3896598	·423102	2·363494	·9209589	4
16	·3789178	·409450	2·442298	·9254303	44	37	·3845639	·416601	2·400377	·9230984	23	57	·3899277	·423445	2·361580	·9208455	3
17	·3791870	·409790	2·440273	·9253201	43	38	·3848324	·416942	2·398411	·9229865	22	58	·3901955	·423788	2·359668	·9207320	2
18	·3794562	·410129	2·438251	·9252097	42	39	·3851008	·417284	2·396449	·9228745	21	59	·3904633	·424131	2·357759	·9206185	1
19	·3797253	·410469	2·436233	·9250993	41	40	·3853693	·417625	2·394488	·9227624	20	60	·3907311	·424474	2·355852	·9205049	0
20	·3799944	·410809	2·434217	·9249888	40											T.B.K.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 67 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 67 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(*The combined* arrangement of tables is original.)

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·3907311	·424474	2·355852	·9205049	60
1	·3909989	·424818	2·353948	·9203919	59
2	·3912660	·425161	2·352046	·9202774	58
3	·3915343	·425505	2·350148	·9201635	57
4	·3918019	·425849	2·348251	·9200496	56
5	·3920695	·426192	2·346358	·9199350	55
6	·3923371	·426536	2·344467	·9198215	54
7	·3926047	·426880	2·342578	·9197073	53
8	·3928722	·427223	2·340692	·9195931	52
9	·3931397	·427566	2·338809	·9194789	51
10	·3934071	·427912	2·336929	·9193644	50
11	·3936745	·428256	2·335050	·9192499	49
12	·3939419	·428600	2·333174	·9191363	48
13	·3942093	·428944	2·331301	·9190207	47
14	·3944766	·429289	2·329431	·9189060	46
15	·3947439	·429633	2·327563	·9187912	45
16	·3950111	·429978	2·325697	·9186763	44
17	·3952783	·430323	2·323834	·9185614	43
18	·3955455	·430668	2·321974	·9184464	42
19	·3958127	·431012	2·320116	·9183313	41
20	·3960798	·431357	2·318260	·9182161	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21–40	[illegible]	[illegible]	[illegible]	[illegible]	39–20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41–60	[illegible]	[illegible]	[illegible]	[illegible]	19–0
′	Cosine.	Cotang.	Tang.	Sine.	′

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Table No. 80.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude — Cosine. Departure — Sine.

LENGTH OF NATURAL SINES, TANGENTS, COT

Dep. 24 DEGREES. Lat. Dep. (Read down.)

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4067366	·445228	2·246036	·9135455	60	21	·4123096	·452568	2·209611	·9110438	39	41	·4176028	·459596	2·175822	·9086297	19
1	·4070024	·445577	2·244279	·9134271	59	22	·4125745	·452918	2·207901	·9109238	38	42	·4178671	·459948	2·174155	·9085082	18
2	·4072681	·445926	2·242524	·9133087	58	23	·4128395	·453269	2·206193	·9108038	37	43	·4181313	·460301	2·172491	·9083866	17
3	·4075337	·446274	2·240772	·9131902	57	24	·4131044	·453620	2·204487	·9106837	36	44	·4183956	·460653	2·170828	·9082649	16
4	·4077993	·446623	2·239021	·9130716	56	25	·4133693	·453970	2·202784	·9105635	35	45	·4186597	·461006	2·169167	·9081432	15
5	·4080649	·446972	2·237273	·9129529	55	26	·4136342	·454321	2·201083	·9104432	34	46	·4189239	·461359	2·167509	·9080214	14
6	·4083305	·447321	2·235528	·9128342	54	27	·4138990	·454672	2·199384	·9103228	33	47	·4191880	·461711	2·165852	·9078995	13
7	·4085960	·447670	2·233784	·9127154	53	28	·4141638	·455023	2·197687	·9102024	32	48	·4194521	·462064	2·164198	·9077775	12
8	·4088615	·448020	2·232043	·9125965	52	29	·4144285	·455375	2·195992	·9100819	31	49	·4197161	·462417	2·162546	·9076554	11
9	·4091269	·448369	2·230304	·9124775	51	30	·4146932	·455726	2·194299	·9099613	30	50	·4199801	·462771	2·160895	·9075333	10
10	·4093923	·448718	2·228567	·9123584	50	31	·4149579	·456077	2·192609	·9098406	29	51	·4202441	·463124	2·159247	·9074111	9
11	·4096577	·449068	2·226833	·9122393	49	32	·4152226	·456429	2·190921	·9097199	28	52	·4205080	·463477	2·157601	·9072888	8
12	·4099230	·449417	2·225100	·9121201	48	33	·4154872	·456780	2·189234	·9095990	27	53	·4207719	·463831	2·155957	·9071665	7
13	·4101883	·449767	2·223370	·9120008	47	34	·4157517	·457132	2·187551	·9094781	26	54	·4210358	·464184	2·154315	·9070140	6
14	·4104536	·450117	2·221643	·9118815	46	35	·4160163	·457483	2·185869	·9093572	25	55	·4212996	·464538	2·152675	·9069215	5
15	·4107189	·450467	2·219917	·9117620	45	36	·4162808	·457835	2·184189	·9092361	24	56	·4215634	·464891	2·151037	·9067989	4
16	·4109841	·450817	2·218194	·9116425	44	37	·4165453	·458187	2·182511	·9091150	23	57	·4218272	·465245	2·149402	·9066762	3
17	·4112492	·451167	2·216473	·9115229	43	38	·4168097	·458539	2·180836	·9089938	22	58	·4220909	·465599	2·147768	·9065535	2
18	·4115144	·451517	2·214754	·9114033	42	39	·4170741	·458891	2·179163	·9088725	21	59	·4223546	·465953	2·146136	·9064307	1
19	·4117795	·451867	2·213037	·9112835	41	40	·4173385	·459243	2·177492	·9087511	20	60	·4226183	·466307	2·144506	·9063078	0
20	·4120445	·452217	2·211323	·9111637	40											J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 65 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 65 DEGREES. Dep

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(*The combined arrangement of tables is original.*)

Table No. 31.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 25 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 25 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4226183	·466307	2·144506	·9063078	60	21	·4281467	·473765	2·110747	·9037093	39	41	·4333970	·480909	2·079394	·9012031	19
1	·4228819	·466661	2·142879	·9061848	59	22	·4284095	·474122	2·109161	·9035847	38	42	·4336591	·481267	2·077846	·9010770	18
2	·4231455	·467016	2·141253	·9060618	58	23	·4286723	·474478	2·107577	·9034600	37	43	·4339212	·481626	2·076300	·9009508	17
3	·4234090	·467370	2·139630	·9059386	57	24	·4289351	·474834	2·105996	·9033353	36	44	·4341832	·481984	2·074756	·9008246	16
4	·4236725	·467725	2·138008	·9058154	56	25	·4291979	·475191	2·104415	·9032105	35	45	·4344453	·482342	2·073214	·9006982	15
5	·4239360	·468079	2·136389	·9056922	55	26	·4294606	·475548	2·102836	·9030856	34	46	·4347072	·482701	2·071674	·9005718	14
6	·4241994	·468434	2·134771	·9055688	54	27	·4297233	·475904	2·101260	·9029606	33	47	·4349692	·483060	2·070135	·9004453	13
7	·4244628	·468789	2·133155	·9054454	53	28	·4299859	·476261	2·099686	·9028356	32	48	·4352311	·483418	2·068599	·9003188	12
8	·4247262	·469143	2·131542	·9053219	52	29	·4302485	·476618	2·098114	·9027105	31	49	·4354930	·483777	2·067064	·9001921	11
9	·4249895	·469498	2·129930	·9051983	51	30	·4305111	·476975	2·096543	·9025853	30	50	·4357548	·484136	2·065531	·9000654	10
10	·4252528	·469853	2·128321	·9050746	50	31	·4307736	·477332	2·094975	·9024600	29	51	·4360166	·484495	2·064000	·8999386	9
11	·4255161	·470209	2·126713	·9049509	49	32	·4310361	·477689	2·093408	·9023347	28	52	·4362784	·484855	2·062471	·8998117	8
12	·4257793	·470564	2·125108	·9048271	48	33	·4312986	·478047	2·091843	·9022092	27	53	·4365401	·485214	2·060944	·8996848	7
13	·4260425	·470919	2·123504	·9047032	47	34	·4315610	·478404	2·090280	·9020838	26	54	·4368018	·485573	2·059418	·8995578	6
14	·4263056	·471275	2·121903	·9045792	46	35	·4318234	·478762	2·088720	·9019582	25	55	·4370634	·485933	2·057895	·8994307	5
15	·4265687	·471630	2·120303	·9044551	45	36	·4320857	·479119	2·087161	·9018325	24	56	·4373251	·486293	2·056373	·8993035	4
16	·4268318	·471986	2·118705	·9043310	44	37	·4323481	·479477	2·085603	·9017068	23	57	·4375866	·486652	2·054853	·8991763	3
17	·4270949	·472342	2·117110	·9042068	43	38	·4326103	·479835	2·084048	·9015810	22	58	·4378482	·487012	2·053334	·8990489	2
18	·4273579	·472697	2·115516	·9040825	42	39	·4328726	·480193	2·082495	·9014551	21	59	·4381097	·487372	2·051818	·8989215	1
19	·4276208	·473053	2·113924	·9039582	41	40	·4331348	·480551	2·080943	·9013292	20	60	·4383711	·487732	2·050303	·8987940	0
20	·4278838	·473409	2·112334	·9038338	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine	′

Lat. 64 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 64 DEGREES. Dep.

Departure (Dep.)—Distance east or west;
...de (Lat.)—Distance north or south.
...d arrangement of tables is original.)

Table No. 82.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES ...

Dep. 26 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 26 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4383711	·487732	2·050303	·8987940	60	21	·4438534	·495317	2·018908	·8960994	39	11	·4490591	·502583	1·989720	·8935021	19
1	·4386326	·488092	2·048791	·8986665	59	22	·4441140	·495679	2·017433	·8959703	38	12	·4493190	·502947	1·988278	·8933714	18
2	·4388940	·488453	2·047280	·8985389	58	23	·4443746	·496041	2·015959	·8958411	37	13	·4495789	·503312	1·986838	·8932406	17
3	·4391553	·488813	2·045770	·8984112	57	24	·4446352	·496404	2·014486	·8957118	36	14	·4498387	·503676	1·985400	·8931098	16
4	·4394166	·489173	2·044263	·8982834	56	25	·4448957	·496766	2·013016	·8955824	35	15	·4500984	·504041	1·983963	·8929789	15
5	·4396779	·489534	2·042757	·8981555	55	26	·4451562	·497129	2·011547	·8954529	34	16	·4503582	·504406	1·982528	·8928480	14
6	·4399392	·489894	2·041254	·8980276	54	27	·4454167	·497492	2·010080	·8953234	33	17	·4506179	·504771	1·981095	·8927169	13
7	·4402004	·490255	2·039751	·8978996	53	28	·4456771	·497855	2·008615	·8951938	32	18	·4508775	·505136	1·979663	·8925858	12
8	·4404615	·490616	2·038251	·8977715	52	29	·4459375	·498218	2·007151	·8950641	31	19	·4511372	·505501	1·978233	·8924546	11
9	·4407227	·490977	2·036753	·8976433	51	30	·4461978	·498581	2·005689	·8949314	30	50	·4513967	·505866	1·976805	·8923234	10
10	·4409838	·491338	2·035256	·8975151	50	31	·4464581	·498944	2·004229	·8948045	29	51	·4516563	·506232	1·975376	·8921920	9
11	·4412448	·491699	2·033761	·8973868	49	32	·4467184	·499308	2·002771	·8946746	28	52	·4519158	·506597	1·973953	·8920606	8
12	·4415059	·492061	2·032268	·8972584	48	33	·4469786	·499671	2·001314	·8945446	27	53	·4521753	·506963	1·972529	·8919291	7
13	·4417668	·492422	2·030776	·8971299	47	34	·4472388	·500035	1·999859	·8944146	26	54	·4524347	·507329	1·971107	·8917975	6
14	·4420278	·492783	2·029287	·8970014	46	35	·4474990	·500398	1·998405	·8942844	25	55	·4526941	·507694	1·969687	·8916659	5
15	·4422887	·493145	2·027799	·8968727	45	36	·4477591	·500762	1·996953	·8941542	24	56	·4529535	·508060	1·968268	·8915342	4
16	·4425496	·493507	2·026313	·8967440	44	37	·4480192	·501126	1·995503	·8940240	23	57	·4532128	·508426	1·966851	·8914024	3
17	·4428104	·493868	2·024828	·8966153	43	38	·4482792	·501490	1·994055	·8938936	22	58	·4534721	·508792	1·965436	·8912705	2
18	·4430712	·494230	2·023346	·8964864	42	39	·4485392	·501854	1·992608	·8937632	21	59	·4537313	·509159	1·964022	·8911385	1
19	·4433319	·494592	2·021865	·8963575	41	40	·4487992	·502218	1·991163	·8936326	20	60	·4539905	·509525	1·962610	·8910065	0
20	·4435927	·494954	2·020386	·8962285	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine	′

Lat. 63 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 63 DEGREES. Dep

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 27 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 27 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4539905	·509525	1·962610	·8910065	60	21	·4594248	·517244	1·933323	·8882166	39	41	·4646845	·524640	1·906066	·8855288	19
1	·4512197	·509891	1·961200	·8908744	59	22	·4596832	·517612	1·931945	·8880830	38	42	·4648420	·525011	1,904719	·8853936	18
2	·4515088	·510258	1·959791	·8907423	58	23	·4599415	·517981	1·930569	·8879492	37	43	·4650996	·525382	1,903373	·8852584	17
3	·4547679	·510625	1·958383	·8906100	57	24	·4601998	·518350	1·929195	·8878154	36	44	·4653571	·525754	1·902029	·8851230	16
4	·4550269	·510991	1·956978	·8904777	56	25	·4604580	·518719	1·927822	·8876815	35	45	·4656145	·526125	1 900687	·8849876	15
5	·4552859	·511358	1·955573	·8903453	55	26	·4607162	·519089	1·926451	·8875475	34	46	·4658719	·526496	1·899348	·8848522	14
6	·4555149	·511725	1·954171	·8902128	54	27	·4609744	·519458	1·925081	·8874134	33	47	·4661293	·526868	1·898006	·8847166	13
7	·4558038	·512093	1·952770	·8900803	53	28	·4612325	·519827	1·923713	·8872793	32	48	·4663866	·527240	1·896668	·8845810	12
8	·4560627	·512460	1·951371	·8899476	52	29	·4614906	·520197	1·922347	·8871451	31	49	·4666439	·527612	1·895332	·8844453	11
9	·4563216	·512827	1·949973	·8898149	51	30	·4617486	·520567	1·920982	·8870108	30	50	·4669012	·527983	1·893997	·8843096	10
10	·4565804	·513195	1·948577	·8896822	50	31	·4620066	·520936	1·919618	·8868765	29	51	·4671584	·528356	1·892663	·8841736	9
11	·4568392	·513562	1·947182	·8895493	49	32	·4622646	·521306	1·918256	·8867420	28	52	·4674156	·528728	1·891331	·8840377	8
12	·4570979	·513930	1·945789	·8894164	48	33	·4625225	·521676	1·916896	·8866075	27	53	·4676727	·529100	1·890000	·8839017	7
13	·4573566	·514298	1·944398	·8892834	47	34	·4627804	·522046	1·915537	·8864730	26	54	·4679298	·529472	1·888671	·8837656	6
14	·4576153	·514665	1·943008	·8891503	46	35	·4630382	·522417	1·914179	·8863383	25	55	·4681869	·529845	1·887343	·8836295	5
15	·4578739	·515033	1·941620	·8890171	45	36	·4632960	·522787	1·912823	·8862036	24	56	·4684439	·530217	1·886017	·8834933	4
16	·4581325	·515401	1·940233	·8888839	44	37	·4635538	·523157	1·911469	·8860688	23	57	·4687009	·530590	1·884692	·8833569	3
17	·4583910	·515770	1·938848	·8887506	43	38	·4638115	·523528	1·910116	·8859339	22	58	·4689578	·530963	1·883369	·8832206	2
18	·4586496	·516138	1·937464	·8886172	42	39	·4640692	·523899	1·908764	8857989	21	59	·4692147	·531336	1·882047	·8830841	1
19	·4589080	·516506	1·936082	·8884838	41	40	·4643269	·524269	1·907414	·8856639	20	60	·4694716	·531709	1·880726	·8829476	0
20	·4591665	·516875	1·934702	·8883503	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine	′

Lat. 62 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 62 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(Combined arrangement of tables is original.)

Table No. 84.

Traverse Table for a Distance = 1.

Latitude -- Cosine. Departure — Sine.

NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1.

Dep. 28 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 28 DEGREES Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4694716	·531709	1·880726	·8829476	60	21	·4748564	·539570	1·853325	·8800633	39	41	·4799683	·547106	1·827799	·8772858	19
1	·4697284	·532082	1·879407	·8828110	59	22	·4751124	·539946	1·852035	·8799251	38	42	·4802235	·547484	1·826537	·8771462	18
2	·4699852	·532455	1·878089	·8826743	58	23	·4753683	·540322	1·850747	·8797869	37	43	·4804786	·547862	1·825276	·8770064	17
3	·4702419	·532829	1·876773	·8825376	57	24	·4756242	·540698	1·849461	·8796486	36	44	·4807337	·548240	1·824017	·8768666	16
4	·4704986	·533202	1·875458	·8824007	56	25	·4758801	·541074	1·848176	·8795102	35	45	·4809888	·548618	1·822759	·8767268	15
5	·4707553	533576	1·874145	·8822638	55	26	·4761359	·541450	1·846892	·8793717	34	46	·4812438	·548997	1·821502	·8765868	14
6	·4710119	·533950	1·872833	·8821269	54	27	·4763917	·541826	1·845609	·8792332	33	47	·4814987	·549375	1·820247	·8764468	13
7	·4712685	·534324	1·871523	·8819899	53	28	·4766474	·542202	1·844328	·8790946	32	48	·4817537	·549754	1·818993	·8763067	12
8	·4715250	·534698	1·870214	·8818527	52	29	·4769031	·542579	1·843049	·8789559	31	49	·4820086	·550133	1·817740	·8761665	11
9	·4717815	·535072	1·868906	·8817155	51	30	·4771588	·542955	1·841770	·8788171	30	50	·4822634	·550512	1·816480	·8760263	10
10	·4720380	·535446	1·867600	·8815782	50	31	·4774144	·543332	1·840494	·8786783	29	51	·4825182	·550891	1·815239	·8758859	9
11	·4722944	·535820	1·866295	·8814409	49	32	·4776700	·543709	1·839218	·8785394	28	52	·4827730	·551270	1·813990	·8757455	8
12	·4725508	·536195	1·864992	·8813035	48	33	·4779255	·544086	1·837944	·8784001	27	53	·4830277	·551650	1·812743	·8756051	7
13	·4728071	·536569	1·863690	·8811660	47	34	·4781810	·544463	1·836671	·8782613	26	54	·4832824	·552029	1·811496	·8754645	6
14	·4730634	·536944	1·862389	·8810284	46	35	·4784364	·544840	1·835399	·8781222	25	55	·4835370	·552409	1·810252	·8753239	5
15	·4733197	·537319	1·861090	·8808907	45	36	·4786919	·545217	1·834129	·8779830	24	56	·4837916	·552789	1·809008	·8751832	4
16	·4735759	·537694	1·859792	·8807530	44	37	·4789472	·545595	1·832861	·8778437	23	57	·4840462	553168	1·807766	·8750425	3
17	·4738321	·538069	1·858496	·8806152	43	38	·4792026	·545972	1·831593	·8777043	22	58	·4843007	·553548	1·806525	·8749016	2
18	·4740882	·538444	1·857201	·8804774	42	39	·4794579	·546350	1·830327	·8775649	21	59	·4845552	·553928	1·805286	·8747607	1
19	·4743443	·538819	1·855908	·8803394	41	40	·4797131	·546728	1·829062	·8774254	20	60	·4848096	·554309	1·804047	·8746197	0
20	·4746004	·539195	1·854615	·8802014	40											J.A.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 61 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 61 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude Lat.)=Distance north or south.
(*The combined* arrangement of tables is original.)

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Length of Natural Sines, Tangents, Cotangents and Cosines when Radius=1

Dep. 29 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 29 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·4848096	·554309	1·804047	·8746197	60	21	·4901433	·562321	1·778340	·8716419	39	41	·4952060	·570004	1·754372	·8687756	19
1	·4850640	·554689	1·802810	·8744786	59	22	·4903968	·562704	1·777130	·8714993	38	42	·4954587	·570389	1·753186	·8686315	18
2	·4853184	·555069	1·801575	·8743375	58	23	·4906503	·563087	1·775921	·8713566	37	43	·4957113	·570775	1·752002	·8684874	17
3	·4855727	·555450	1·800340	·8741963	57	24	·4909038	·563471	1·774714	·8712138	36	44	·4959639	·571161	1·750819	·8683431	16
4	·4858270	·555831	1·799107	·8740550	56	25	·4911572	·563854	1·773507	·8710710	35	45	·4962165	·571547	1·749637	·8681988	15
5	·4860812	·556211	1·797875	·8739137	55	26	·4914105	·564237	1·772302	·8709281	34	46	·4964690	·571933	1·748456	·8680544	14
6	·4863354	·556592	1·796645	·8737722	54	27	·4916638	·564621	1·771098	·8707851	33	47	·4967215	·572319	1·747276	·8679100	13
7	·4865895	·556973	1·795416	·8736307	53	28	.4919171	·565005	1·769895	·8706420	32	48	·4969740	·572705	1·746098	·8677655	12
8	·4868436	·557355	1·794198	·8734891	52	29	·4921704	·565388	1·768694	·8704989	31	49	·4972264	·573091	1·744921	·8676209	11
9	·4870977	·557736	1·792961	·8733475	51	30	·4924236	·565772	1·767494	·8703557	30	50	·4974787	·573478	1·743745	·8674762	10
10	·4873517	·558117	1·791736	·8732058	50	31	·4926767	·566156	1·766295	·8702124	29	51	·4977310	·573864	1·742570	·8673314	9
11	·4876057	·558499	1·790512	·8730640	49	32	·4929298	·566541	1·765097	·8700691	28	52	·4979833	.574251	1·741396	·8671866	8
12	·4878597	·558881	1·789289	·8729221	48	33	·4931829	·566925	1·763900	·8699256	27	53	·4982355	·574638	1·740224	·8670417	7
13	·4881136	·559262	1·788067	·8727801	47	34	·4934359	·567309	1·762705	·8697821	26	54	·4984877	·575025	1·739053	·8668967	6
14	·4883674	·559644	1·786847	·8726381	46	35	·4936889	·567694	1·761511	·8696386	25	55	·4987399	·575412	1·737883	·8667517	5
15	·4886212	·560026	1·785628	·8724960	45	36	·4939419	·568079	1·760318	·8694949	24	56	·4989920	·575799	1·736714	·8666066	4
16	·4888750	·560409	1·784410	·8723538	44	37	·4941948	·568463	1·759126	·8693512	23	57	·4992441	·576187	1·735546	·8664614	3
17	·4891288	·560791	1·783194	·8722116	43	38	·4944476	·568848	1·757936	·8692074	22	58	·4994961	·576574	1·734380	·8663161	2
18	·4893825	·561173	1·781979	·8720693	42	39	·4947005	·569233	1·756747	·8690636	21	59	·4997491	·576962	1·733214	·8661708	1
19	·4896361	·561556	1·780765	·8719269	41	40	·4949532	·569619	1·755559	·8689196	20	60	·5000000	·577350	1·732050	·8660254	0
20	·4898897	·561939	1·779552	·8717844	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 60 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 60 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

...VERSE TABLE FOR A DISTANCE = 1.

...de = Cosine. Departure = Sine.

′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′
0	·5000000	·577350	1·732050	·8660254	60	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	·5002519	·577738	1·730887	·8658799	59	22	·5055319	·586914	1·706732	·8628079	38	42	·5105429	·593756	1·684191	·8598523	18
2	·5005037	·578126	1·729726	·8657344	58	23	·5057828	·586305	1·705595	·8626608	37	43	·5107930	·594150	1·683070	·8597037	17
3	·5007556	·578514	1·728565	·8655887	57	24	·5060338	·586696	1·704458	·8625137	36	44	·5110431	·594543	1·681962	·8595551	16
4	·5010073	·578902	1·727406	·8654430	56	25	·5062846	·587087	1·703323	·8623664	35	45	·5112931	·594937	1·680848	·8594064	15
5	·5012591	·579291	1·726247	·8652973	55	26	·5065355	·587478	1·702189	·8622191	34	46	·5115431	·595331	1·679736	·8592576	14
6	·5015107	·579679	1·725090	·8651514	54	27	·5067863	·587870	1·701055	·8620717	33	47	·5117930	·595725	1·678625	·8591088	13
7	·5017624	·580068	1·723934	·8650055	53	28	·5070370	·588261	1·699923	·8619243	32	48	·5120429	·596119	1,677515	·8589599	12
8	·5020140	·580457	1·722779	·8648595	52	29	·5072877	·588653	1·698792	·8617768	31	49	·5122927	·596514	1·676406	·8588109	11
9	·5022655	·580846	1·721626	·8647134	51	30	·5075384	·589045	1·697663	·8616292	30	50	·5125425	·596908	1·675298	·8586619	10
10	·5025170	·581235	1·720473	·8645673	50	31	·5077890	·589436	1·696534	·8614815	29	51	·5127923	·597303	1·674192	·8585127	9
11	·5027685	·581624	1·719322	·8644211	49	32	·5080396	·589828	1·695406	·8613337	28	52	·5130120	·597697	1·673086	·8583635	8
12	·5030199	·582013	1·718172	·8642748	48	33	·5082901	·590221	1·694280	·8611859	27	53	·5132916	·598092	1·671981	·8582143	7
13	·5032713	·582403	1·717023	·8641284	47	34	·5085406	·590613	1·693155	·8610380	26	54	·5135413	·598487	1·670878	·8580649	6
14	·5035227	·582793	1·715875	·8639820	46	35	·5087910	·591005	1·692030	·8609901	25	55	·5137908	·598882	1·669775	·8579155	5
15	·5037740	·583182	1·714728	·8638355	45	36	·5090414	·591398	1·690907	·8607420	24	56	·5140404	·599278	1·668674	·8577660	4
16	·5040252	·583572	1·713582	·8636889	44	37	·5092918	·591791	1·689785	·8605939	23	57	·5142899	·599673	1·667574	·8576164	3
17	·5042765	·583962	1·712438	·8635423	43	38	·5095421	·592183	1·688664	·8604457	22	58	·5145393	·600069	1·666474	·8574668	2
18	·5045276	·584352	1·711294	·8633956	42	39	·5097924	·592576	1·687544	·8602975	21	59	·5147887	·600464	1·665376	·8573171	1
19	·5047788	·584743	1·710152	·8632488	41	40	·5100426	·592969	1·686426	·8601491	20	60	·5150381	·600860	1·664279	·8571673	0
20	·5050298	·585133	1·709011	·8631019	40											J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. **59** DEGREES. Dep. Lat. (Read up.) Dep. Lat. **59** DEGREES. Dep.

...eparture (Dep.)—Distance east or west.
...atitude (Lat.)—Distance north or south.
...e *combined* arrangement of tables is original.)

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Length of Natural Sines, Tangents, Cotangents and Cosines when Radius = 1

Dep. 31 DEGREES. Lat. | Dep. (Read down.) Lat. | Dep. 31 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5150381	·600860	1·664279	·8571673	60	21	·5202646	·609205	1·641482	·8540051	39	41	·5252241	·617210	1·620192	·8509630	19
1	·5152874	·601256	1·663183	·8570174	59	22	·5205130	·609604	1·640408	·8538538	38	42	·5254717	·617612	1·619138	·8508111	18
2	·5155367	·601652	1·662088	·8568675	58	23	·5207613	·610003	1·639335	·8537023	37	43	·5257191	·618014	1·618085	·8506592	17
3	·5157859	·602049	1·660994	·8567175	57	24	·5210096	·610402	1·638263	·8535508	36	44	·5259665	·618416	1·617033	·8505053	16
4	·5160351	·602445	1·659901	·8565674	56	25	·5212579	·610801	1·637191	·8533992	35	45	·5262139	·618818	1·615982	·8503523	15
5	·5162842	·602841	1·658809	·8564173	55	26	·5215061	·611201	1·636121	·8532475	34	46	·5264613	·619221	1·614932	·8501991	14
6	·5165333	·603238	1·657718	·8562671	54	27	·5217543	·611601	1·635052	·8530958	33	47	·5267085	·619623	1·613882	·8500459	13
7	·5167824	·603635	1·656629	·8561168	53	28	·5220024	·612000	1·633984	·8529440	32	48	·5269558	·620026	1·612834	·8498927	12
8	·5170314	·604032	1·655540	·8559664	52	29	·5222505	·612400	1·632917	·8527921	31	49	·5272030	·620429	1·611787	·8497394	11
9	·5172804	·604429	1·654452	·8558160	51	30	·5224986	·612800	1·631851	·8526402	30	50	·5274502	·620832	1·610741	·8495860	10
10	·5175293	·604826	1·653306	·8556655	50	31	·5227466	·613201	1·630786	·8524981	29	51	·5276973	·621235	1·609696	·8494325	9
11	·5177782	·605224	1·652280	·8555149	49	32	·5229915	·613601	1·629722	·8523360	28	52	·5279443	·621638	1·608652	·8492790	8
12	·5180270	·605621	1·651196	·8553643	48	33	·5232424	·614001	1·628659	·8521830	27	53	·5281914	·622041	1·607609	·8491254	7
13	·5182758	·606019	1·650112	·8552135	47	34	·5234903	·614402	1·627597	·8520316	26	54	·5284383	·622445	1·606567	·8489717	6
14	·5185246	·606417	1·649030	·8550627	46	35	·523738!	·614803	·626530	·8518793	25	55	·5286853	·622848	1·605526	·8488179	5
15	·5187733	·606814	1·647949	·8549119	45	36	·5239859	·615204	1·625476	·8517269	24	56	·5289322	·623252	1·604485	·8486641	4
16	·5190219	·607213	1·646868	·8547609	44	37	·5242336	·615605	1·624417	·8515745	23	57	·5291790	·623656	1·603446	·8485102	3
17	·5192705	·607611	1·645789	·8546099	43	38	·5244813	·616006	1 623359	·8514219	22	58	·5294258	·624060	1·602408	·8483562	2
18	·5195191	·608009	1·644711	·8544588	42	39	·5247290	·616407	1·622302	·8512693	21	59	·5296726	·624465	1·601370	·8482022	1
19	·5197676	·608408	1·643633	·8543077	41	40	·5249766	·616809	1·621246	·8511167	20	60	·5299193	·624869	1·600334	·8480481	0
20	·5200161	·608806	1·642557	·8541564	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 58 DEGREES. Dep. | Lat. (Read up.) Dep. | Lat. 58 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(Combined arrangement of tables is original.)

Table No. 88.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

Dep. **32** DEGREES. Lat. Dep. (Read down.) Lat. Dep. **32** DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5299193	·624869	1·600334	·8480481	60
1	·5301659	·625273	1·599299	·8478939	59
2	·5304125	·625678	1·598264	·8477397	58
3	·5306591	·626083	1·597231	·8475853	57
4	·5309057	·626488	1·596198	·8474309	56
5	·5311521	·626893	1·595167	·8472765	55
6	·5313986	·627298	1·594136	·8471219	54
7	·5316450	·627704	1·593107	·8469673	53
8	·5318913	·628109	1·592078	·8468126	52
9	·5321376	·628515	1·591050	·8466579	51
10	·5323839	·628921	1·590023	·9165030	50
11	·5326301	·629327	1·588997	8463481	49
12	·5328763	·629733	1·587973	·8461932	48
13	·5331224	·630139	1·586949	·8460381	47
14	·5333685	·630546	1·585926	·8458830	46
15	·5336145	·630953	1·584904	·8457278	45
16	·5338605	·631359	1·583883	8455726	44
17	·5341065	·631766	1·582862	8454172	43
18	·5343523	·632173	1·581843	·8452618	42
19	·5345982	·632581	1·580825	·8451064	41
20	·5348440	·632988	1·579807	·8449508	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·5350898	·633395	1·578791	·8447952	39
22	·5353355	·633803	1·577776	·8446395	38
23	·5355812	·634211	1·576761	·8444838	37
24	·5358268	·634619	1·575747	·8443279	36
25	·5360724	·635027	1·574735	·8441720	35
26	·5363179	·635435	1·573723	·8440161	34
27	·5365634	·635844	1·572712	·8438600	33
28	·5368089	·636252	1·571702	·8437039	32
29	·5370543	·636661	1·570693	·8435477	31
30	·5372996	·637070	1·569685	·8433914	30
31	·5375449	·637479	1·568678	·8432351	29
32	·5377902	·637888	1·567672	·8430787	28
33	·5380354	·638297	1·566666	·8429222	27
34	·5382806	·638707	1·565662	·8427657	26
35	·5385257	·639116	1·564659	·8426091	25
36	·5387708	·639526	1·563656	·8424524	24
37	·5390158	·639936	1·562654	·8422956	23
38	·5392608	·640346	1·561654	·8421388	22
39	·5395058	·640756	1·560654	·9419819	21
40	·5397507	·641167	1·559655	·8418249	20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·5399955	·641577	1·558657	·8416679	19
42	·5402403	·641988	1·557660	·8415108	18
43	·5404851	·642399	1·556663	·8413536	17
44	·5407298	·642810	1·555668	·9411963	16
45	·5409745	·643221	1·554674	·8410390	15
46	·5412191	·643632	1·553680	·8408816	14
47	·5414637	·644044	1·552688	·8407241	13
48	5417082	·644456	1·551696	·8405666	12
49	.5419527	·644867	1·550705	·8404090	11
50	·5421971	·645279	1·549715	·8402513	10
51	·5424415	·645691	1·548726	·8400936	9
52	·5426859	·646104	1·547738	·8399357	8
53	·5429302	·646516	1·546751	·8397778	7
54	·5431744	·646929	1·545764	·8396199	6
55	·5434187	·647341	1·544779	·8394618	5
56	·5436628	·647754	1·543794	·8393037	4
57	·5439069	·648167	1·542810	·8391455	3
58	·5441510	·648580	1·541828	·8389873	2
59	·5443951	·648994	1·540846	·8388290	1
60	·5446390	·649407	1·539865	·8386706	0
				J.B.R	
′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. **57** DEGREES. Dep. Lat. (Read up.) Dep Lat. **57** DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(*The combined* arrangement of tables is original.)

Table No. 89.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 33 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 33 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5446390	·649407	1·539865	·8386706	60	21	·5497520	·658127	1·519463	·8353279	39	41	·5546024	·666496	1·500382	·8321155	19
1	·5448830	·649821	1·538884	·8385121	59	22	·5499950	·658544	1·518501	·8351680	38	42	·5548444	·666917	1·499436	·8319541	18
2	·5451269	·650235	1·537905	·8383536	58	23	·5502379	·658961	1·517540	·8350080	37	43	·5550864	·667337	1·498492	·8317927	17
3	·5453707	·650649	1·536927	·8381950	57	24	·5504807	·659378	1·516579	·8348479	36	44	·5553283	·667758	1·497548	·8316312	16
4	·5456145	·651063	1·535949	·8380363	56	25	·5507236	·659796	1·515620	·8346877	35	45	·5555702	·668178	1·496605	·8314696	15
5	·5458581	·651477	1·534972	·8378775	55	26	·5509663	·660213	1·514661	·8345275	34	46	·5558121	·668599	1·495663	·8313080	14
6	·5461020	·651891	1·533996	·8377187	54	27	·5512091	·660631	1·513703	·8343672	33	47	·5560539	·669020	1·494722	·8311463	13
7	·5463456	·652306	1·533021	·8375598	53	28	·5514518	·661049	1·512746	·8342068	32	48	·5562956	·669441	1·493782	·8309845	12
8	·5465892	·652721	1·532047	·8374009	52	29	·5516944	·661467	1·511790	·8340463	31	49	·5565373	·669863	1·492842	·8308226	11
9	·5468328	·653136	1·531074	·8372418	51	30	·5519370	·661885	1·510835	·8338858	30	50	·5567790	·670284	1·491903	·8306607	10
10	·5470763	·653551	1·530102	·8370827	50	31	·5521795	·662304	1·509880	·8337252	29	51	·5570206	·670706	1·490965	·8304987	9
11	·5473198	·653966	1·529130	·8369236	49	32	·5524220	·662722	1·508927	·8335646	28	52	·5572621	·671128	1·490028	·8303366	8
12	·5475632	·654381	1·528160	·8367643	48	33	·5526645	·663141	1·507974	·8334038	27	53	·5575036	·671550	1·489092	·8301745	7
13	·5478066	·654797	1·527190	·8366050	47	34	·5529069	·663560	1·507022	·8332430	26	54	·5577451	·671972	1·488157	·8300123	6
14	·5480499	·655212	1·526221	·8364456	46	35	·5531492	·663979	1·506071	·8330822	25	55	·5579865	·672394	1·487222	·8298500	5
15	·5482932	·655628	1·525253	·8362862	45	36	·5533915	·664398	1·505121	·8329212	24	56	·5582279	·672816	1·486288	·8296877	4
16	·5485365	·656044	1·524286	·8361266	44	37	·5536338	·664817	1·504171	·8327602	23	57	·5584692	·673239	1·485355	·8295252	3
17	·5487797	·656460	1·523320	·8359670	43	38	·5538760	·665237	1·503222	·8325991	22	58	·5587105	·673662	1·484423	·8293628	2
18	·5490228	·656877	1·522354	·8358074	42	39	·5541182	·665657	1·502275	·8324390	21	59	·5589517	·674085	1·483491	·8292002	1
19	·5492659	·657293	1·521389	·8356476	41	40	·5543603	·666076	1·501328	·8322768	20	60	·5591929	·674508	1·482561	·8290376	0
20	·5495090	·657710	1·520426	·8354878	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 56 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 56 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(Combined arrangement of tables is original.)

Table No. 90.

55°

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude — Cosine. Departure — Sine.

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES

Dep. 34 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 34 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5591929	·674508	1·482561	·8290376	60	21	·5642467	·683433	1·463200	·8256062	39	41	·5690403	·692002	1·445081	·8223096	19
1	·5594340	·674931	1·481631	·8288749	59	22	·5644869	·683860	1·462287	·8254420	38	42	·5692795	·692432	1·444183	·8221440	18
2	·5596751	·675355	1·480702	·8287121	58	23	·5647270	·684287	1·461374	·8252778	37	43	·5695187	·692863	1·443286	·8219784	17
3	·5599162	·675779	1·479773	·8285493	57	24	·5649670	·684714	1·460463	·8251135	36	44	·5697577	·693293	1·442389	·8218127	16
4	·5601572	·676202	1·478846	·8283864	56	25	·5652070	·685141	1·459552	·8249491	35	45	·5699968	·693724	1·441494	·8216469	15
5	·5603981	·676626	1·477919	·8282234	55	26	·5654469	·685569	1·458642	·8247847	34	46	·5702357	·694155	1·440599	·8214811	14
6	·5606390	·677050	1·476993	·8280603	54	27	·5656868	·685996	1·457732	·8246202	33	47	·5704747	·694586	1·439704	·8213152	13
7	·5608798	·677475	1·476068	·8278972	53	28	·5659267	·686424	1·456824	·8244550	32	48	·5707136	·695018	1·438811	·8211492	12
8	·5611206	·677899	1·475144	·8277340	52	29	·5661665	·686852	1·455916	·8242909	31	49	·5709524	·695149	1·437918	·8209832	11
9	·5613614	·678324	1·474221	·8275708	51	30	·5664062	·687281	1·455009	·8241262	30	50	·5711912	·695881	1·437026	·8208170	10
10	·5616021	·678749	1·473298	·8274074	50	31	·5666459	·687709	1·454102	·8239614	29	51	·5714299	·696313	1·436135	·8206509	9
11	·5618428	·679174	1·472376	·8272440	49	32	·5668856	·688137	1·453197	·8237965	28	52	·5716686	·696745	1·435245	·8204846	8
12	·5620834	·679599	1·471455	·8270806	48	33	·5671252	·688566	1·452292	·8236316	27	53	·5719073	·697177	1·434355	·8203183	7
13	·5623239	·680024	1·470535	·8269170	47	34	·5673648	·688995	1·451388	·8234666	26	54	·5721459	·697609	1·433466	·8201519	6
14	·5625645	·680450	1·469615	·8267534	46	35	·5676043	·689424	1·450485	·8233015	25	55	·5723844	,698042	1·432578	·8199854	5
15	·5628049	·680875	1·468696	·8265897	45	36	·5678437	·689853	1·449582	·8231364	24	56	·5726229	·698474	1·431690	·8198189	4
16	·5630453	·681301	1·467778	·8264260	44	37	·5680832	·690283	1·448680	·8229712	23	57	·5728614	·698907	1.430803	·8196523	3
17	·5632857	·681727	1·466861	·8262622	43	38	·5683225	·690712	1·447779	·8228059	22	58	·5730998	·699340	1.429917	·8194856	2
18	·5635260	·682153	1·465945	·8260983	42	39	·5685619	·691142	1·446879	·8226405	21	59	·5733381	·699774	1.429032	·8193189	1
19	·5637663	·682580	1·465029	·8259343	41	40	·5688011	·691572	1·445980	·8224751	20	60	·5735764	·700207	1.428148	·8191520	0
20	·5640066	·683006	1·464114	·8257703	40											J. B. H.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 55 DEGREES Dep. Lat. (Read up.) Dep. Lat. 55 DEGREES. Dep

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Traverse Table ... Distance = 1.

Latitude = Cosine. Departure = Sine.

Dep. 35 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 35 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5735764	·700207	1·428148	·8191520	60
1	·5738147	·700643	1·427264	·8189859	59
2	·5740529	·701079	1·426381	·8188182	58
3	·5742911	·701506	1·425498	·8186512	57
4	·5745292	·701943	1·424617	·8184841	56
5	·5747672	·702377	1·423736	·8183169	55
6	·5750053	·702811	1·422856	·8181497	54
7	·5752432	·703246	1·421976	·8179824	53
8	·5754811	·703681	1·421097	·8178151	52
9	·5757190	·704116	1·420220	·8176476	51
10	·5759568	·704551	1·419342	·8174801	50
11	·5761946	·704986	1·418466	·8173125	49
12	·5764323	·705422	1·417590	·8171449	48
13	·5766700	·705858	1·416715	·8169772	47
14	·5769076	·706294	1·415840	·8168094	46
15	·5771452	·706730	1·414967	·8166416	45
16	·5773827	·707166	1·414094	·8164736	44
17	·5776202	·707602	1·413222	·8163056	43
18	·5778576	·708039	1·412350	·8161376	42
19	·5780950	·708476	1·411479	·8159695	41
20	·5783323	·708913	1·410609	·8158013	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21–40	[illegible]	[illegible]	[illegible]	[illegible]	39–20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41–59	[illegible]	[illegible]	[illegible]	[illegible]	19–1
60	[illegible]	[illegible]	[illegible]	·8090170	0
				J.B.S.	
′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 54 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 54 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(Combined arrangement of tables is original.)

Table No. 92.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

LENGTH OF NATURAL SINES, TANGENTS, ...

Dep. 36 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 36 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·5877853	·726542	1·376381	·8090170	60	21	·5927163	·735917	1·358848	·8054113	39	41	·5973919	·744924	1·342417	·8019495	19
1	·5880206	·726987	1·375540	·8088460	59	22	·5929505	·736366	1·358020	·8052389	38	42	·5976251	·745377	1·341602	·8017756	18
2	·5882558	·727431	1·374699	·8086749	58	23	·5931847	·736814	1·357193	·8050664	37	43	·5978583	·745829	1·340788	·8016018	17
3	·5884910	·727876	1·373859	·8085037	57	24	·5934189	·737263	1·356367	·8048938	36	44	·5980915	·746282	1·339975	·8014278	16
4	·5887262	·728321	1·373019	·8083325	56	25	·5936530	·737712	1·355541	·8047211	35	45	·5983246	·746735	1·339162	·8012538	15
5	·5889613	·728767	1·372180	·8081612	55	26	·5938871	·738162	1·354716	·8045484	34	46	·5985577	·747188	1·338350	·8010797	14
6	·5891964	·729212	1·371342	·8079899	54	27	·5941211	·738611	1·353891	·8043756	33	47	·5987906	·747642	1·337538	·8009056	13
7	·5894314	·729658	1·370504	·8078185	53	28	·5943550	·739061	1·353068	·8042028	32	48	·5990236	·748095	1·336727	·8007314	12
8	·5896663	·730104	1·369667	·8076470	52	29	·5945889	·739511	1·352244	·8040299	31	49	·5992565	·748549	1·335917	·8005571	11
9	·5899012	·730550	1·368831	·8074754	51	30	·5948228	·739961	1·351422	·8038569	30	50	·5994893	·749003	1·335107	·8003827	10
10	·5901361	·730996	1·367995	·8073038	50	31	·5950566	·740411	1·350600	·8036838	29	51	·5997221	·749457	1·334298	·8002083	9
11	·5903709	·731442	1·367161	·8071321	49	32	·5952904	·740861	1·349779	·8035107	28	52	·5999549	·749911	1·333490	·8000338	8
12	·5906057	·731889	1·366326	·8069603	48	33	·5955241	·741312	1·348958	·8033375	27	53	·6001876	·750366	1·332682	·7998593	7
13	·5908404	·732336	1·365493	·8067885	47	34	·5957577	·741763	1·348139	·8031642	26	54	·6004202	·750821	1·331875	·7996847	6
14	·5910750	·732783	1·364660	·8066166	46	35	·5959913	·742214	1·347319	·8029909	25	55	·6006528	·751276	1·331068	·7995100	5
15	·5913096	·733230	1·363827	·8064446	45	36	·5962249	·742665	1·346501	·8028175	24	56	·6008854	·751731	1·330262	·7993352	4
16	·5915442	·733677	1·362996	·8062726	44	37	·5964584	·743117	1.345683	·8026440	23	57	·6011179	·752186	1·329457	·7991604	3
17	·5917787	·734125	1·362165	·8061005	43	38	·5966918	·743568	1.344865	·8024705	22	58	·6013503	·752642	1·328652	·7989855	2
18	·5920132	·734573	1·361335	·8059283	42	39	·5969252	·744020	1.344049	·8022969	21	59	·6015827	·753098	1·327848	·7988105	1
19	·5922476	·735021	1·360505	·8057560	41	40	·5971586	·744472	1.343233	·8021232	20	60	·6018150	·753554	1·327044	·7986355	0
20	·5924819	735469	1·359676	·8055837	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 53 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 53 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(The combined arrangement of tables is original.)

Table No. 93.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine.

Length of Natural Sines, Tangents, Cotangents and Cosines when Radius = 1

Dep. 37 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 37 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6018150	·753554	1·327044	·7986355	60	21	·6066824	·763175	1·310314	·7949444	39	41	·6112969	·772422	1·294627	·7914014	19
1	·6020473	·754010	1·326242	·7984604	59	22	·6069136	·763636	1·309523	·7947678	38	42	·6116270	·772887	1·293848	·7912235	18
2	·6022795	·754466	1·325439	·7982853	58	23	·6071447	·764096	1·308734	·7945913	37	43	·6117572	·773352	1·293071	·7910456	17
3	.6025117	·754923	1·324638	·7981100	57	24	·6073758	·764557	1·307945	·7944146	36	44	·6119870	·773817	1·292294	·7908676	16
4	·6027439	·755379	1·323837	·7979347	56	25	·6076069	·765018	1·307157	·7942379	35	45	·6122173	·774282	1·291517	·7906896	15
5	·6029760	·755836	1·323036	·7977594	55	26	·6078379	·765480	1·306369	·7940611	34	46	·6124473	·774748	1·290742	·7905115	14
6	·6032080	·756294	1·322237	·7975839	54	27	·6080689	·765941	1·305582	·7938843	33	47	·6126772	·775213	1·289966	·7903333	13
7	·6034400	·756751	1·321437	·7974084	53	28	·6082998	·766403	1·304796	·7937074	32	48	·6129071	·775679	1·289192	·7901550	12
8	·6036719	·757209	1·320639	·7972329	52	29	·6085306	·766864	1·304010	·7935304	31	49	·6131369	·776145	1·288418	·7899767	11
9	·6039038	·757666	1·319841	·7970572	51	30	·6087614	·767327	1·303225	·7933533	30	50	·6133666	·776611	1·287644	·7897983	10
10	·6041356	·758124	1·319044	·7968815	50	31	·6089922	·767789	1·302440	·7931762	29	51	·6135964	·777078	1·286871	·7896198	9
11	·6043674	·758582	1·318247	·7967058	49	32	·6092229	·768251	1·301656	·7929990	28	52	·6138260	·777544	1·286099	·7894413	8
12	·6045991	·759041	1·317451	·7965299	48	33	·6094535	·768714	1·300873	·7928218	27	53	·6140556	·778011	1·285327	·7892627	7
13	·6048308	·759499	1·316655	·7963540	47	34	·6096841	·769177	1·300090	·7926445	26	54	·6142852	·778478	1·284556	·7890841	6
14	·6050624	·759958	1·315861	·7961780	46	35	·6099147	·769640	1·299308	·7924671	25	55	·6145147	·778946	1·283786	·7889054	5
15	·6052940	·760417	1.315066	·7960020	45	36	·6101452	·770103	1·298526	·7922896	24	56	·6147442	·779413	1·283016	·7887266	4
16	·6055255	·760876	1·314273	·7958259	44	37	·6103756	·770567	1·297745	·7921121	23	57	·6149736	·779881	1·282246	·7885477	3
17	·6057570	·761336	1.313480	·7956497	43	38	·6106060	·771030	1·296964	·7919345	22	58	·6152029	·780349	1·281477	·7883688	2
18	·6059884	·761795	1.312687	·7954735	42	39	·6108363	·771494	1·296185	·7917569	21	59	·6154322	·780817	1·280709	·7881898	1
19	·6062198	·762255	1.311895	.7952972	41	40	·6110666	·771958	1·295405	·7915792	20	60	·6156615	·781285	1·279941	·7880108	0
20	·6064511	·762715	1.311104	·7951208	40											Lat.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 52 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 52 DEGREES. Dep.

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
(The combined arrangement of tables is original.)

Table No. 94.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

NATURAL SINES, TANGENTS, COTANGENTS, COSINES.

Dep. 38 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 38 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6156615	·781286	1·279941	·7880108	60	21	·6204636	·791170	1·263950	·7842352	39	41	·6250156	·800673	1·248948	·7806123	19
1	·6158907	·781754	1·279174	·7878316	59	22	·6206917	·791643	1·263195	·7840547	38	42	·6252427	·801151	1·248204	·7804304	18
2	·6161198	·782222	1·278407	·7876524	58	23	·6209198	·792116	1·262440	·7838741	37	43	·6254696	·801628	1·247460	·7802485	17
3	·6163489	·782691	1·277641	·7874732	57	24	·6211478	·792590	1·261686	·7836935	36	44	·6256966	·802106	1·246716	·7800665	16
4	·6165780	·783161	1·276876	·7872939	56	25	·6213757	·793064	1·260932	·7835127	35	45	·6259235	·802584	1·245974	·7798845	15
5	·6168069	·783630	1·276111	·7871145	55	26	·6216036	·793537	1·260179	·7833320	34	46	·6261503	·803063	1·245232	·7797021	14
6	·6170359	·784100	1·275347	·7869350	54	27	·6218314	·794012	1·259426	·7831511	33	47	·6263771	·803541	1·244490	·7795202	13
7	·6172648	·784570	1·274583	·7867555	53	28	·6220592	·794486	1·258674	·7829702	32	48	·6266038	·804020	1·243749	·7793380	12
8	·6174936	·785040	1·273820	·7865759	52	29	·6222870	·794961	1·257923	·7827892	31	49	·6268305	·804499	1·243008	·7791557	11
9	·6177224	·785510	1·273057	·7863963	51	30	·6225146	·795435	1·257172	·7826082	30	50	·6270571	·804979	1·242268	·7789733	10
10	·6179511	·785980	1·272295	·7862165	50	31	·6227423	·795911	1·256421	·7824270	29	51	·6272837	·805458	1·241529	·7787909	9
11	·6181798	·786451	1·271534	·7860367	49	32	·6229698	·796386	1·255672	·7822459	28	52	·6275102	·805938	1·240790	·7786084	8
12	·6184084	·786922	1·270773	·7858569	48	33	·6231974	·796861	1·254922	·7820646	27	53	·6277366	·806418	1·240051	·7784258	7
13	·6186370	·787393	1·270013	·7856770	47	34	·6234248	·797337	1·254174	·7818833	26	54	·6279631	·806898	1·239313	·7782431	6
14	·6188655	·787864	1·269253	·7854970	46	35	·6236522	·797813	1·253426	·7817019	25	55	·6281894	·807378	1·238576	·7780604	5
15	·6190939	·788336	1·268494	·7853169	45	36	·6238796	·798289	1·252678	·7815205	24	56	·6284157	·807859	1·237839	·7778777	4
16	·6193224	·788808	1·267735	·7851368	44	37	·6241069	·798765	1·251931	·7813390	23	57	·6286420	·808340	1·237103	·7776949	3
17	·6195507	·789280	1·266977	·7849566	43	38	·6243342	·799242	1·251184	·7811574	22	58	·6288682	·808821	1·236367	·7775120	2
18	·6197790	·789752	1·266219	·7847764	42	39	·6245614	·799719	1·250438	·7809757	21	59	·6290943	·809302	1·235631	·7773290	1
19	·6200073	·790224	1·265462	·7845961	41	40	·6247885	·800196	1·249693	·7807940	20	60	·6293204	·809784	1·234897	·7771460	0
20	·6202355	·790697	1·264706	·7844157	40											J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 51 DEGREES. Dep. Lat. (Read up.) Dep. Lat. 51 DEGREES. Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(The combined arrangement of tables is original.)

Table No. 95.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sin

LENGTH OF NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS=1

Dep. 39 DEGREES. Lat. Dep. (Read down.) Lat. Dep. 39 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6293204	·809784	1·234897	·7771460	60	21	·6340559	·819948	1·219588	·7732872	39	41	·6385440	·829724	1·205219	·7695853	19
1	·6295464	·810265	1·234162	·7769629	59	22	·6342808	·820435	1·218865	·7731027	38	42	·6387678	·830216	1·204505	·7693996	18
2	·6297724	·810747	1·233429	·7767797	58	23	·6345057	·820922	1·218142	·7729182	37	43	·6389916	·830707	1·203793	·7692137	17
3	·6299983	·811230	1·232696	·7765965	57	24	·6347305	·821409	1·217419	·7727336	36	44	·6392153	·831199	1·203081	·7690278	16
4	·6302242	·811712	1·231963	·7764132	56	25	·6349553	·821896	1·216698	·7725489	35	45	·6394390	·831691	1·202369	·7688418	15
5	·6304500	·812195	1·231231	·7762298	55	26	·6351800	·822384	1·215976	·7723642	34	46	·6396626	·832183	1·201658	·7686558	14
6	·6306758	·812678	1·230499	·7760464	54	27	·6354046	·822871	1·215256	·7721794	33	47	·6398862	·832675	1·200947	·7684697	13
7	·6309015	·813161	1·229768	·7758629	53	28	·6356292	·823359	1·214535	·7719945	32	48	·6401097	·833168	1·200237	·7682835	12
8	·6311272	·813644	1·229038	·7756794	52	29	·6358537	·823847	1·213816	·7718096	31	49	·6403332	·833661	1·199527	·7680973	11
9	·6313528	·814128	1·228308	·7754957	51	30	·6360782	·824336	1·213097	·7716246	30	50	·6405566	·834154	1·198818	·7679110	10
10	·6315784	·814611	1·227579	·7753121	50	31	·6363026	·824825	1·212378	·7714395	29	51	·6407799	·834648	1·198109	·7677246	9
11	·6318039	·815095	1·226849	·7751283	49	32	·6365270	·825314	1·211660	·7712544	28	52	·6410032	·835141	1·197401	·7675382	8
12	·6320293	·815580	1·226121	·7749445	48	33	·6367513	·825803	1·210942	·7710692	27	53	·6412264	·835635	1·196693	·7673517	7
13	·6322547	·816064	1·225393	·7747606	47	34	·6369756	·826292	1·210225	·7708840	26	54	·6414496	·836129	1·195986	·7671652	6
14	·6324800	·816549	1·224665	·7745767	46	35	·6371999	·826782	1·209508	·7706986	25	55	·6416728	·836624	1·195279	·7669785	5
15	·6327053	·817034	1·223938	·7743926	45	36	·6374240	·827271	1·208792	·7705132	24	56	·6418958	·837118	1·194573	·7667918	4
16	·6329306	·817519	1·223212	·7742086	44	37	·6376481	·827762	1·208076	·7703278	23	57	·6421189	·837613	1·193867	·7666051	3
17	·6331557	·818004	1·222486	·7740244	43	38	·6378721	·828252	1·207361	·7701423	22	58	·6423418	·838108	1·193162	·7664183	2
18	·6333809	·818490	1·221761	·7738402	42	39	·6380961	·828742	1·206646	·7699567	21	59	·6425647	·838604	1·192457	·7662314	1
19	·6336059	·818976	1·221036	·7736559	41	40	·6383201	·829233	1·205932	·7697710	20	60	·6427876	·839099	1·191753	·7660444	0
20	·6338310	·819462	1·220312	·7734716	40												

Departure (Dep.)—Distance east or west.
Latitude (Lat.)—Distance north or south.
The combined arrangement of tables is origina

Table No. 96.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

49 DEGREES. NATURAL SINES, TANGENTS, COTANGENTS AND COSINES WHEN RADIUS = 1.

Dep. 49 DEGREES. Lat. — Dep. (Read down.) Lat. — Dep. 49 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6427876	·839099	1·191753	·7660444	60	21	·6474551	·849563	1·177075	·7621036	39	41	·6518778	·859629	1·163291	·7583240	19
1	·6430104	·839595	1·191049	·7658574	59	22	·6476767	·850064	1·176382	·7619152	38	42	·6520984	·860135	1·162607	·7581343	18
2	·6432332	·840091	1.190346	·7656704	58	23	·6478984	·850565	1·175688	·7617268	37	43	6523189	·860641	1·161923	·7579446	17
3	·6434559	·840587	1·189643	·7654832	57	24	·6481199	·851066	1·174996	·7615383	36	44	·6525394	·861148	1·161240	·7577548	16
4	·6436785	·841084	1·188941	·7652960	56	25	·6483414	·851568	1·174303	·7613497	35	45	·6527598	·861655	1·160557	·7575650	15
5	·6439011	·841581	1·188239	·7651087	55	26	·6485628	·852070	1·173612	·7611611	34	46	·6529801	·862162	1·159874	·7573751	14
6	·6441236	·842078	1·187538	·7649214	54	27	·6487842	·852572	1·172920	·7609724	33	47	·6532004	862669	1·159192	7571851	13
7	·6443461	·842575	1·186837	·7647340	53	28	·6490056	·853075	1·172229	·7607837	32	48	·6534206	·863176	1·158511	·7569951	12
8	·6445685	·843073	1·186136	·7645465	52	29	·6492268	·853577	1·171539	·7605949	31	49	·6536408	·863684	1·157830	·7568050	11
9	·6447909	·843570	1·185437	·7643590	51	30	·6494480	·854080	1·170849	·7604060	30	50	·6538609	·864192	1·157149	·7566149	10
10	·6150132	·844068	1·184737	·7641714	50	31	·6496692	·854583	1·170160	·7602170	29	51	·6540810	·864700	1·156469	·7564246	9
11	·6452355	·844567	1·184038	·76398[illegible]	49	32	·6498903	·855087	1·169471	·7600280	28	52	·6543010	·865209	1·155789	·7562343	8
12	·6454577	·845065	1·183340	·7637960	48	33	·6501114	·855591	1·168782	·7598389	27	53	·6545209	·865718	1·155110	·7560439	7
13	·6456798	·845564	1·182642	·7636082	47	34	·6503324	·856095	1·168094	·7596498	26	54	·6547408	·866227	1·154431	·7558535	6
14	·6459019	·846063	1·181944	·7634204	46	35	·6505533	·856599	1·167407	·7594606	25	55	·6549607	·866736	1·153753	·7556630	5
15	·6461240	·846562	1·181247	·7632325	45	36	·6507742	·857103	1·166720	·7592713	24	56	·6551804	·867246	1·153075	·7554724	4
16	·6463460	·847062	1·180551	·7630445	44	37	·6509951	·857608	1·166033	·7590820	23	57	·6554002	·867755	1·152397	·7552818	3
17	·6465679	·847561	1·179855	·7628564	43	38	·6512158	·858113	1·165347	·7588926	22	58	·6556198	·868265	1·151721	·7550911	2
18	·6467898	·848061	1·179159	·7626683	42	39	·6514366	·858618	1·164661	·7587031	21	59	·6558395	·868776	1·151044	·7549004	1
19	·6470116	·848561	1·178464	·7624802	41	40	·6516572	·859124	1·163976	·7585136	20	60	·6560590	·869286	1·150368	·7547096	0
20	·6472334	·849062	1·177769	·7622919	40												
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 49 DEGREES. Dep. — Lat. (Read up.) Dep. — Lat. 49 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(The combined arrangement of tables is original.)

Table No. 97.

Traverse Table for a Distance = 1.

Natural Sines, Cosines, Tangents and Cotangents when Radius = 1

Latitude = Cosine. Departure = Sine.

Dep. Lat. Dep. (Continued.) Lat. Dep. 41 Degrees. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′
0	[illegible]	[illegible]	[illegible]	[illegible]	60
1	[illegible]	[illegible]	[illegible]	[illegible]	59
2	[illegible]	[illegible]	[illegible]	[illegible]	58
3	[illegible]	[illegible]	[illegible]	[illegible]	57
4	[illegible]	[illegible]	[illegible]	·7541288	56
5	[illegible]	[illegible]	[illegible]	·7539457	55
6	[illegible]	[illegible]	[illegible]	·7537546	54
7	[illegible]	[illegible]	1·146321	·7535634	53
8	[illegible]	[illegible]	1·145648	·7533721	52
9	[illegible]	[illegible]	1·144976	·7531808	51
10	[illegible]	[illegible]	1·144304	·7529894	50
10	·6585?16	·874406	1·143632	·7527980	50
11	·6587?0?	·874920	1·142961	·7526065	49
12	·658?895	·875433	1·142290	·7524149	48
13	·6589087	·875947	1·141620	·7522233	47
14	·6591271	·876462	1·140950	·7520316	46
15	·6593458	·876976	1·140281	·7518398	45
16	·6595645	·877491	1·139612	·7516480	44
17	·6597831	·878006	1·138944	·7514561	43
18	·6600017	·878521	1·138276	·7512641	42
19	·6602202	·879037	1·137608	·7510721	41
20	·6604386	·879552	1·136941	·7508800	40
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
21	·6606570	·880067	1·136274	·7506879	39
22	·6608754	·880582	1·135608	·7504957	38
23	·6610936	·881101	1·134942	·7503034	37
24	·6613119	·881618	1·134277	·7501111	36
25	·6615300	·882135	1·133612	·7499187	35
26	·6617482	·882653	1·132947	·7497262	34
27	·6619662	·883170	1·132283	·7495337	33
28	·6621842	·883688	1·131620	·7493411	32
29	·6624022	·884206	1·130957	·7491484	31
30	·6626200	·884725	1·130294	·7489557	30
31	·6628379	·885244	1·129632	·7487629	29
32	·6630557	·885763	1·128970	·7485701	28
33	·6632734	·886282	1·128308	·7483772	27
34	·6634910	·886801	1·127647	·7481842	26
35	·6637087	·887321	1·126987	·7479912	25
36	·6639262	·887841	1·126327	·7477981	24
37	·6641437	·888361	1·125667	·7476049	23
38	·6643612	·888882	1·125008	·7474117	22
39	·6645785	·889403	1·124349	·7472184	21
40	·6647959	·889924	1·123690	·7470251	20
′	Cosine.	Cotang.	Tang.	Sine.	′

′	Sine.	Tang.	Cotang.	Cosine.	′
41	·6650131	·890445	1·123032	·7468317	19
42	·6652304	·890967	1·122375	·7466382	18
43	·6654475	·891489	1·121718	·7464446	17
44	·6656646	·892011	1·121061	·7462510	16
45	·6658817	·892534	1·120405	·7460574	15
46	·6660987	·893056	1·119749	·7458636	14
47	·6663156	·893579	1·119094	·7456699	13
48	·6665325	·894103	1·118439	·7454760	12
49	·6667493	·894626	1·117784	·7452821	11
50	·6669661	·895150	1·117130	·7450881	10
51	·6671828	·895674	1·116476	·7448941	9
52	·6673994	·896199	1·115823	·7446999	8
53	·6676160	·896723	1·115170	·7445058	7
54	·6678326	·897248	1·114518	·7443115	6
55	·6680490	·897773	1·113866	·7441173	5
56	·6682655	·898299	1·113214	·7439229	4
57	·6684818	·898825	1·112563	·7437285	3
58	·6686981	·899351	1·111912	·7435340	2
59	·6689144	·899877	1·111262	·7433394	1
60	·6691306	·900404	1·110612	·7431448	0
′	Cosine.	Cotang.	Tang.	Sine.	′

48 Degrees.

Departure (Dep.) = Distance east or west,
Latitude (Lat.) = Distance north or south.
(Continued arrangement of tables is original.)

Table No. 98.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Sine

Dep. 47 DEGREES. Lat. | Dep. (Read down.) Lat. | Dep. 47 DEGREES.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6691306	·900404	1·110612	·7431448	60	21	·6736577	·911526	1·097060	·7390435	39	41	·6779459	·922235	1,084322	·7351118	19
1	·6693468	·900930	1·109963	·7429502	59	22	·6738727	·912059	1·096420	·7388475	38	42	·6781597	·922773	1·083680	·7349146	18
2	·6695628	·901458	1·109314	·7427554	58	23	·6740876	·912592	1·095779	·7386515	37	43	·6783734	·923312	1·083057	·7347173	17
3	·6697789	·901985	1·108665	·7425606	57	24	·6743024	·913125	1·095139	·7384553	36	44	·6785871	·923851	1·082425	·7345199	16
4	·6699948	·902513	1·108017	·7423658	56	25	·6745172	·913659	1·094500	·7382592	35	45	·6788007	·924390	1·081793	·7343225	15
5	·6702108	·903041	1·107369	·7421708	55	26	·6747319	·914192	1·093861	·7380629	34	46	·6790143	·924930	1·081162	·7341250	14
6	·6704266	·903569	1·106721	·7419758	54	27	·6749466	·914727	1·093222	·7378666	33	47	·6792278	·925470	1·080532	·7339275	13
7	·6706424	·904097	1·106075	·7417808	53	28	·6751612	·915261	1·092584	·7376703	32	48	·6794413	·926010	1·079901	·7337299	12
8	·6708582	·904626	1·105428	·7415857	52	29	·6753757	·915796	1·091946	·7374738	31	49	·6796547	·926550	1·079271	·7335322	11
9	·6710739	·905155	1·104782	·7413905	51	30	·6755902	·916331	1·091308	·7372773	30	50	·6798681	·927091	1·078642	·7333345	10
10	·6712895	·905685	1·104136	·7411953	50	31	·6758046	·916866	1·090671	·7370808	29	51	·6800813	·927632	1·078013	·7331367	9
11	·6715051	·906214	1·103491	·7410000	49	32	·6760190	·917402	1·090034	·7368842	28	52	·6802946	·928173	1·077384	·7329388	8
12	·6717206	·906744	1·102846	·7408046	48	33	·6762333	·917937	1·089398	·7366875	27	53	·6805078	·928715	1·076756	·7327409	7
13	·6719361	·907274	1·102201	·7406092	47	34	·6764476	·918474	1·088762	·7364908	26	54	·6807209	·929257	1·076128	·7325429	6
14	·6721515	·907805	1·101557	·7404137	46	35	·6766618	·919010	1·088126	·7362940	25	55	·6809339	·929799	1·075500	·7323449	5
15	·6723668	·908336	1·100914	·7402181	45	36	·6768760	·919547	1·087491	·7360971	24	56	·6811469	·930342	1·074873	·7321467	4
16	·6725821	·908867	1·100270	·7400225	44	37	·6770901	·920084	1·086857	·7359002	23	57	·6813599	·930884	1·074246	·7319486	3
17	·6727973	·909398	1·099628	·7398268	43	38	·6773041	·920621	1·086222	·7357032	22	58	·6815728	·931428	1·073620	·7317503	2
18	·6730125	·909930	1·098985	·7396311	42	39	·6775181	·921159	1·085588	·7355061	21	59	·6817856	·931971	1·072994	·7315521	1
19	·6732276	·910461	1·098343	·7394353	41	40	·6777320	·921696	1·084955	·7353090	20	60	·6819984	·932515	1·072368	·7313537	0
20	·6734427	·910994	1·097702	·7392394	40											J.S.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 47 DEGREES. Dep. | Lat. (Read up.) Dep. | Lat. 47 DEGREES Dep.

Departure (Dep.) = Distance east or west.
Latitude (Lat.) = Distance north or south.
(*The combined arrangement of tables is original.*)

43°

Table No. 99.

Traverse Table for a Distance = 1.

Latitude = Cosine. Departure = Si

Natural Sines, Tangents, Cotangents and Cosines when Radius = 1

Dep. [illegible] DEGREES Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21	[illegible]	[illegible]	[illegible]	·7271740	39	41	·6906721	·955064	1·047049	·7231681	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	[illegible]	[illegible]	[illegible]	·7269743	38	42	·6908824	·955620	1·046440	·7229671	18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	·7267745	37	43	·6910927	·956177	1·045831	·7227661	17
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	·7265747	36	44	·6913029	·956734	1·045222	·7225651	16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25	[illegible]	[illegible]	[illegible]	·7263748	35	45	·6915131	·957291	1·044613	·7223640	15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	·6870101	[illegible]	[illegible]	·7261748	34	46	·6917232	·957849	1·044005	·7221628	14
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27	[illegible]	[illegible]	[illegible]	·7259748	33	47	·6919332	·958407	1·043397	·7219615	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28	[illegible]	[illegible]	[illegible]	·7257747	32	48	·6921432	·958965	1·042790	·7217602	12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29	[illegible]	·948411	1·054394	·7255746	31	49	·6923531	·959524	1·042183	·7215589	11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	·948964	1·053780	·7253744	30	50	·6925630	·960082	1·041576	·7213574	10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31	[illegible]	·949517	1·053166	·7251741	29	51	·6927728	·960642	1·040970	·7211559	9
[illegible]	[illegible]	[illegible]	[illegible]	·7291677	49	32	·6887768	·950070	1·052553	·7249738	28	52	·6929825	·961201	1·040364	·7209544	8
[illegible]	[illegible]	[illegible]	[illegible]	·7289680	48	33	·6889873	·950624	1·051940	·7247734	27	53	·6931922	·961761	1·039758	·7207528	7
[illegible]	[illegible]	[illegible]	[illegible]	·7287696	47	34	·6891981	·951178	1·051327	·7245729	26	54	·6934018	·962321	1·039153	·7205511	6
[illegible]	[illegible]	·940157	1·063651	·7285703	46	35	·6894089	·951732	1·050715	·7243724	25	55	·6936114	·962881	1·038548	·7203494	5
[illegible]	[illegible]	·940706	[illegible]	·7283710	45	36	·6896195	·952287	1·050103	·7241719	24	56	·6938209	·963442	1·037944	·7201476	4
16	[illegible]	·941254	1·062411	·7281716	44	37	·6898302	·952842	1·049492	·7239712	23	57	·6940304	·964003	1·037340	·7199457	3
17	[illegible]	·941803	1·061792	·7279722	43	38	·6900407	·953397	1·048880	·7237705	22	58	·6942398	·964565	1·036736	·7197438	2
18	[illegible]	·942352	1·061174	·7277728	42	39	·6902512	·953952	1·048270	·7235698	21	59	·6944491	·965126	1·036133	·7195419	1
19	·6860300	·942901	1·060556	·7275732	41	40	·6904617	·954508	1·047659	·7233690	20	60	·6946584	·965688	1·035530	·7193398	0
20	·6862416	·943451	1·059938	·7273736	40												

Table No. 100.

TRAVERSE TABLE FOR A DISTANCE = 1.

Latitude = Cosine. Departure = Sine.

Dep. 44 DEGREES. Lat. | Dep. (Read down.) Lat. | Dep. 44 DEGREES. Lat.

′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′	′	Sine.	Tang.	Cotang.	Cosine.	′
0	·6946584	·965688	1·035530	·7193398	60	21	·6990396	·977564	1·022950	·7150830	39	41	·7031879	·989006	1·011115	·7110041	19
1	·6948676	·966251	1·034927	·7191377	59	22	·6992476	·978133	1·022355	·7148796	38	42	·7033947	·989582	1·010527	·7107995	18
2	·6950767	·966813	1·034325	·7189355	58	23	·6994555	·978702	1·021760	·7146762	37	43	·7036014	·990158	1·009939	·7105948	17
3	6952858	·967376	1·033723	·7187333	57	24	·6996633	·979272	1·021166	·7144727	36	44	·7038081	·990734	1·009352	·7103901	16
4	·6954949	·967939	1·033122	·7185310	56	25	·6998711	·979842	1·020572	·7142691	35	45	·7040147	·991311	1·008764	·7101854	15
5	·6957039	·968503	1·032520	·7183287	55	26	·7000789	·980412	1·019978	·7140655	34	46	·7042213	·991888	1·008178	·7099806	14
6	·6959128	·969067	1·031919	·7181263	54	27	·7002866	·980983	1·019385	·7138618	33	47	·7044278	·992465	1·007591	·7097757	13
7	·6961217	·969631	1·031319	·7179238	53	28	·7004942	·981554	1·018792	·7136581	32	48	·7046342	·993042	1·007005	·7095707	12
8	·6963305	·970196	1·030719	·7177213	52	29	·7007018	·982125	1·018199	·7134543	31	49	·7048406	·993620	1·006420	·7093657	11
9	·6965392	·970761	1·030119	·7175187	51	30	·7009093	·982697	1·017607	·7132504	30	50	·7050469	·994199	1·005834	·7091607	10
10	·6967479	·971326	1·029520	·7173161	50	31	·7011167	·983269	1·017015	·7130465	29	51	·7052532	·994777	1·005249	·7089556	9
11	·6969565	·971891	1·028921	·7171134	49	32	·7013241	·983841	1·016423	·7128426	28	52	·7054594	·995356	1·004665	·7087504	8
12	·6971651	·972457	1·028322	·7169106	48	33	·7015314	·984414	1·015832	·7126385	27	53	·7056655	·995935	1·004080	·7085451	7
13	·6973736	·973023	1·027724	·7167078	47	34	·7017387	·984987	1·015241	·7124344	26	54	·7058716	·996515	1·003496	·7083398	6
14	·6975821	·973590	1·027126	·7165049	46	35	·7019459	·985560	1·014651	·7122303	25	55	·7060776	·997095	1·002913	·7081345	5
15	·6977905	·974156	1·026528	·7163019	45	36	·7021531	·986133	1·014061	·7120260	24	56	·7062835	·997675	1·002329	·7079291	4
16	·6979988	·974724	1·025931	·7160989	44	37	·7023601	.986707	1·013471	·7118218	23	57	·7064894	·998256	1·001746	·7077236	3
17	·6982071	·975291	1·025334	·7158959	43	38	·7025672	.987282	1·012881	·7116174	22	58	·7066953	·998837	1·001164	·7075180	2
18	·6984153	·975859	1·024738	·7156927	42	39	·7027741	.987856	1·012292	·7114130	21	59	·7069011	·999418	1·000581	·7073124	1
19	·6986234	·976427	1·024141	·7154895	41	40	·7029811	.988431	1·011703	·7112086	20	60	·7071068	1·00000	1·000000	·7071068	0
20	·6988315	·976995	1·023546	·7152863	40											J.B.R.	
′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′	′	Cosine.	Cotang.	Tang.	Sine.	′

Lat. 45 DEGREES. Dep | Lat (Read up.) Dep. | Lat. 45 DEGREES. Dep.

Departure (Dep.)=Distance east or west.
Latitude (Lat.)=Distance north or south.
(*The combined arrangement* of tables is original.)

CURVES.

To avoid reference to the index, when the above subject is under consideration, the following alphabetical list of some of the frequently used tables and information, as found in this work is given.

Table No. 101.

	Number of Table
Angular Measure, see page 78 or,	19
Arc, any or 1°, length of,	49
Chords, long, table of,	106
CIRCLES:—	
Area of equivalents, etc.,	48
" " circum., etc., diam. in twelfths,	52-52F
" " " " " " tenths,	53-53E
" " " " " " eighths, etc.,	54-54B
" parts of, see page 52	
Circumference, Diam., Radius, formulae for,	49
Diam. of certain circular areas, see page 21.	
Cosines, tables of,	56-100
Cotangents, tables of,	56-100
Deflection distances for chords of 100 feet,	104
Functions, trigometric, see pages 78-81.	
Minutes and seconds in decimals of a degree,	50
Ordinates, for 100 ft. chords, table of,	105
" " bending rails,	105A
Radian, length of, etc., see page 78.	
Radii, for 100 ft. chords, table of,	104
Sines, tables of,	56-100
Tangents, actual, length of for a 1° curve,	107
Tangents, tables of,	56-100
Tangential distances, for chords of 100 feet,	104
Traverse tables, for each minute of quadrant,	56-100

GENERAL CASE OF CIRCULAR CURVES.

A CIRCULAR CURVE is simply a part or the whole (generally a part) of the circumference of a circle. Its most frequent application in practice is shown in Figure 22, where two straight lines a l and D e are connected by the curved line a b d e, thus avoiding the angle D, formed by the intersection of the two straight lines. This angle D represents the change in direction, and inasmuch as the curved line at a is, (as it must be being a part of the circumference) at right angles to the radius a c, and is also at right angles to the radius c e at e for the same reason, the change in direction represented by the angle D is the same as the curvature or *change in* direction of the curved line a b d e. The two

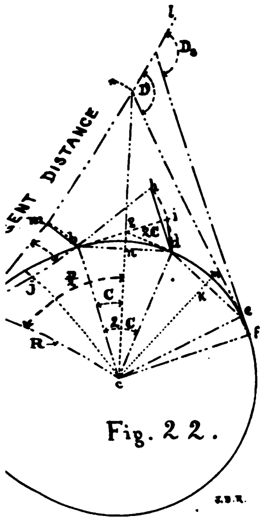


Fig. 22.

lines or TANGENTS a l and D e MUST also be at right angles to the radius at the POINTS OF TANGENT, a and e respectively. The dotted lines, a b, b d and d e are CHORDS (chs) of equal length, generally taken 100 ft. long. Any distance as dotted line e f, shorter than a b, b d or d e, is called a SUB-CHORD, (sub-ch.) and the change in direction between the points a and f, or the angle subtended by three equal chords and the sub-chord e f is rep-
d by the angle D_s.

ɩL ANGLE (2C) =
angle as b c d subtended at the centre of the cir-
ɩ 100 ft. chord as b d = DEGREE OF CURVATURE.

:TION ANGLE (D_a) =
angle as h b d, included between any chord as a b
ed and the next chord b d.

NTIAL ANGLE (T_a) =
angle as m a b included between a tangent to
ve and a chord from the point of tangent a. i b d
her tangential angle and is equal to m a b.

CENTRAL ANGLE is always equal to the De-
ı angle or to TWICE the Tangential angle.

DEFLECTION ANGLE is always equal to the
ıl angle or to TWICE the Tangential angle.

TANGENTIAL ANGLE is always equal to ONE-
of the Central angle or to ONE-HALF of the
tion angle.

CTION DISTANCE OR CHORD DEFLECTION* (D_d) =
· chord as hd which subtends a deflection angle
l. The radius of the arc of which the deflection
ce is the chord = the length of the chord of the
Radius bh = bd, the chord of curve.

e note under Table No. 103.

TANGENTIAL DISTANCE OR TANGENT DEFLECTION* (T_d) =

Any chord as mb which subtends a tangential angle as mab. The radius of the arc of which the deflection distance is the chord = the length of the chord of the curve. Radius a m = ab, the chord of curve.

TANGENT DISTANCE (d) =

The distance from the intersection angle D to either POINT OF TANGENT, a or e. aD always equals in length De.

Though not exactly correct, in practice it is near enough to assume the DEFLECTION DISTANCE = TWICE the TANGENTIAL DISTANCE, when the radius of curvature (radius of circle) exceeds 300 feet. For actual lengths of each, see Table No. 104.

MIDDLE ORDINATE =

Any line as km from the centre of a chord de to the centre of the corresponding arc de. Other ordinates are parallel to it and between it and d or e.

Let L represent the length of the curve in 100 ft. stations, then by formulae relative to Figs. 19 and 20 we have from Fig. 22:—

Table No. 102.

d = Radius × tangent $\frac{D}{2}$ because angle gca = ½ an-

In practice we can assume the sines of small angles proportional to the angles themselves and we have,

$C \cdot C_s :: ch : ch_s^* :: 100' : ch_s$ 7

Therefore, $C_s = \dfrac{C \times ch_s}{100}$ 8

EXAMPLE :—

If sub chord is 20 ft., we have $C_s = \dfrac{C \times 20'}{100'} = \frac{1}{5}$ C.

The Radius varies inversely as sine of degree of urve and assuming that the sines of small angles are roportional to the angles themselves, it (the radius) aries inversely as the degree (2 C) of the curve.

If the central angle (2C) = 1°, C (one half central ngle) = $\frac{1}{2}$° = 30′, and from table 56 or by calculation re have.

Sin C = 0.0087265; substituting this value in equa. on (4) we have.

$$\text{Radius} = \frac{50}{0.0087265} = 5729.65 \text{ ft. or approximately}$$

730 feet as the RADIUS of a ONE DEGREE CURVE.

In like manner the radius of any degree curve can be btained, and knowing the radius, it is a simple matter f solving right angle triangles, (see Fig. 20) for the ength of their sides and angles to find any other trigonetric function or function of the curve required, but to acilitate rapid work, tables of Radii, Ordinates, etc., re in common use and will be found in this work. See ist as given in Table No. 101 or index.

Table No. 103.

FORMULAE FOR CIRCULAR CURVES.

(See also Table No. 102.)

Radius of Any Curve =
- Tangent distance × cot $\frac{1}{2}$ intersection angle, or 1
- $\frac{1}{2}$ chord × cosec of tangential angle, or 1a
- $\frac{1}{2}$ chord ÷ sin of tangential angle, or 1b
- $\frac{1}{2}$ chord ÷ sin of $\frac{1}{2}$ deflection angle, or get from proportion below.

Sin deflection angle : sin $\frac{1}{2}$ (180° — deflection angle) :: chord : Radius 1c

*Ch_s — *abbreviation for* sub-chord.

Table No. 103. (Continued.)

Sine of Tangential Angle	=	One-half of chord ÷ Radius ...	2
Tangential Angle	=	Angle corresponding to sine obtained by formula next above as found in Tables 56 to 100 inclusive	3
Tangential Distance	=	2 × chord × sin ½ tangential angle or for 100′ chs: 5000′ ÷ radius or see Table No. 104	4
Tangent Distance	=	Radius × tan ½ intersection angle (Angle D. in Fig. 22,) or for rapid work use Table No. 107, ...	5
Deflection Angle	=	Tangential angle × 2 or approximately for 100′ chords, 5730 ft. ÷ Radius. (See also Table No. 104)	6
Deflection Distance for 100′ chords	=	10000′ ÷ Radius in feet, (†) see also Table No. 104	
Deflection Distance for any Given Radius and equal length chords	=	(½ chord ÷ Radius) × 2 chord, or ...... chord² ÷ Radius. or...... 2 × chord × sine of tangential angle	
Middle Ordinate	=	See Table No. 105, (100′chs.) or, ... " " " 105 A for rails; or ... ½ ch. × tan of ½ tangential angle; .... or when middle ordinate <radius, Radius — $\sqrt{\text{radius}^2 - \frac{1}{2}\text{chord}^2}$, ... or when middle ordinate >radius; Radius + $\sqrt{\text{radius}^2 - \frac{1}{2}\text{chord}^2}$, or.. ½ tangential distance, (approximately) when chord is short in proportion	9

Table No. 103. (Continued.)

Chord of Curve =

- (Radius × 2) ÷ cosec tangential angle or, 11
- Radius × 2 × sine tangential angle or, 11a
- Radius × 2 × sine ½ deflection angle or, 11b
- Radius × 2 × sine ½ (5730 ÷ radius) or, 11c
- $\sqrt{\text{Radius} \times \text{deflection distance}}$ or 11d
- Tangential distance ÷ (2 × sin ½ tangential angle) or, 11e
- Deflection distance ÷ (2 × sin tangential angle) or, 11f
- (2 × middle ordinate) ÷ tangent ½ tangential angle or, 11g
- (2 × middle ordinate) × cotangent ½ tangential angle or, 11h
- without use of functions of angle.
- 2 × square root of (2 × radius × middle ordinate) 11i

Ordinate of Sub-chord = (Corresponding ordinate for a 100' chord × square of sub-chord) ÷ 10000.

For angle subtended by a sub-chord, see Table No. 102.

Angle for given Distance and Deflection Distance =

$$\frac{57.3 \times \text{given deflection distance}}{\text{given distance}} \text{ or } \frac{\text{given deflection distance}}{.01745\dagger \times \text{given distance}}$$

Deflection distance for any given angle and distance = given distance × .01745 × angle.

To find radius of curve of existing track quickly, without a transit, stretch a string of convenient length tightly between two points on inside of outer rail; measure middle ordinate or greatest distance of string from inside of outer rail, then (square of ½ length of string in inches, plus square of middle ordinate in inches) ÷ 24 × middle ordinate in inches = radius of curve in feet, or use Table No. 105 or 105A.

NOTE.—In Tables 103 and 104 and elsewhere in this work, the words "deflection distance" and "tangential distance" are used believing that the terms are less liable to confuse than the words "chord deflection" and "tangent deflection," as used by some engineers. Both distances have to do with chords; and so far as possible, the word "deflection" should apply to angles, not distances.

†01745 = *deflection distance* for 1° for 1 foot.

Table No. 104.

Table of Radii, Deflection and Tangential Distances for Various Deflection Angles From 0° 1′ to 2° 44′, for 100′ Chords.

Tangential Angle = Deflection Angle ÷ 2.

Deflection Angle °	Deflection Angle ′	Radius	Deflection Dist.	Tangential Dist.	Deflection Angle °	Deflection Angle ′	Radius	Deflection Dist.	Tangential Dist.
		Feet	Feet	Feet			Feet	Feet	Feet
	1	343775	.029	.014		57	6032	1.656	.828
	2	171887	.058	.029		58	5928	1.685	.842
	3	114592	.087	.043		59	5827	1.715	.857
	4	85944	.116	.058	1		5730	1.745	.872
	5	68755	.145	.072		2	5545	1.802	.901
	6	57296	.174	.087		4	5372	1.860	.930
	7	49111	.203	.101		6	5209	1.918	.959
	8	42972	.232	.116		8	5056	1.976	.988
	9	38197	.262	.131		10	4912	2.036	1.018
	10	34378	.291	.145		12	4775	2.094	1.047
	11	31254	.320	.160		14	4646	2.152	1.076
	12	28648	.349	.174		16	4524	2.210	1.105
	13	26444	.378	.189		18	4408	2.268	1.134
	14	24556	.407	.203		20	4298	2.326	1.163
	15	22918	.436	.218		22	4193	2.384	1.192
	16	21485	.465	.232		24	4093	2.443	1.221
	17	20222	.494	.247		26	3998	2.501	1.250
	18	19098	.523	.261		28	3907	2.559	1.279
	19	18093	.552	.276		30	3820	2.617	1.308
	20	17189	.581	.290		32	3737	2.676	1.338
	21	16371	.610	.305		34	3657	2.734	1.367
	22	15627	.639	.319		36	3581	2.793	1.396
	23	14947	.668	.334		38	3508	2.851	1.425
	24	14324	.697	.348		40	3438	2.908	1.454
	25	13751	.727	.363		42	3370	2.967	1.483
	26	13222	.756	.378		44	3306	3.025	1.512
	27	12732	.785	.392		46	3243	3.083	1.541
	28	12278	.814	.407		48	3183	3.141	1.570
	29	11855	.843	.421		50	3126	3.199	1.599
	30	11459	.872	.436		52	3069	3.258	1.629
	31	11089	.900	.450		54	3016	3.316	1.658
	32	10743	.930	.465		56	2964	3.374	1.687
	33	10418	.959	.479		58	2914	3.432	1.716
	34	10111	.988	.494	2		2865	3.490	1.745
	35	9822	1.017	.508		2	2818	3.548	1.774
	36	9549	1.046	.523		4	2772	3.606	1.803
	37	9291	1.075	.537		6	2729	3.665	1.832
	38	9046	1.104	.552		8	2686	3.723	1.861
	39	8814	1.133	.566		10	2644	3.781	1.890
	40	8594	1.162	.581		12	2604	3.839	1.919
	41	8384	1.191	.595		14	2566	3.897	1.948
	42	8185	1.221	.610		16	2528	3.956	1.978
	43	7994	1.250	.625		18	2491	4.014	2.007
	44	7814	1.279	.639		20	2456	4.072	2.036
	45	7640	1.308	.654		22	2421	4.130	2.065
	46	7474	1.337	.668		24	2387	4.188	2.094
	47	7315	1.366	.683		26	2355	4.246	2.123
	48	7162	1.395	.697		28	2323	4.305	2.152
	49	7016	1.424	.712		30	2292	4.363	2.182
	50	6876	1.453	.726		32	2262	4.421	2.210
	51	6741	1.482	.741		34	2232	4.479	2.239
	52	6611	1.511	.755		36	2204	4.538	2.269
	53	6487	1.540	.770		38	2176	4.596	2.298
	54	6367	1.569	.784		40	2149	4.653	2.326
	55	6251	1.598	.799		42	2122	4.712	2.356
	56	6139	1.627	.813		44	2096	4.770	2.385

Table No. 104. (Continued.)

TABLE OF RADII, DEFLECTION AND TANGENTIAL DI
TANCES FOR VARIOUS DEFLECTION ANGLES FROM
2° 46' to 40°, for 100' Chords.

Tangential Angle = Deflection Angle ÷ 2.

Deflection Angle °	'	Radius	Deflection Dist.	Tangential Dist-	Deflection Angle °	'	Radius	Deflection Dist.	Tangential Dis
		Feet	Feet	Feet			Feet	Feet	Fee
2	46	2071	4.828	2.414	6		955.4	10.47	5.23
	48	2046	4.886	2.443		10	939.7	10.76	5.38
	50	2023	4.944	2.472		20	905.0	11.04	5.52
	52	1999	5.002	2.501		30	882.0	11.34	5.670
	54	1976	5.060	2.530		40	859.5	11.63	5.815
	56	1953	5.118	2.559		50	838.9	11.92	5.960
	58	1932	5.176	2.588	7		819.0	12.21	6.105
3		1910	5.235	2.618		10	807.4	12.50	6.250
	2	1889	5.293	2.646		20	781.9	12.79	6.395
	4	1868	5.351	2.675		30	764.5	13.08	6.540
	6	1848	5.409	2.704		40	748.0	13.37	6.685
	8	1828	5.468	2.734		50	732.0	13.66	6.830
	10	1810	5.526	2.763	8		716.8	13.95	6.975
	12	1790	5.584	2.792		30	674.6	14.81	7.405
	14	1772	5.642	2.821	9		637.3	15.68	7.840
	16	1754	5.700	2.850		30	603.8	16.55	8.275
	18	1736	5.758	2.879	10		573.7	17.43	8.715
	20	1719	5.817	2.908		30	546.4	18.30	9.150
	22	1702	5.875	2.937	11		521.7	19.17	9.585
	24	1685	5.933	2.966		30	499.1	20.05	10.03
	26	1669	5.992	2.996	12		478.3	20.94	10.47
	28	1653	6.050	3.025		30	459.3	21.79	10.90
	30	1637	6.108	3.054	13		441.7	22.64	11.34
	32	1621	6.166	3.083		30	425.5	23.51	11.77
	34	1606	6.224	3.112	14		410.3	24.37	12.21
	36	1591	6.282	3.141		30	396.2	25.24	12.65
	38	1577	6.340	3.170	15		383.1	26.11	13.08
	40	1563	6.398	3 199		30	370.8	26.94	13.52
	42	1549	6.456	3.228	16		359.3	27.83	13.95
	44	1534	6.515	3.257		30	348.4	28.70	14.38
	46	1521	6.574	3.287	17		338.3	29.56	14.82
	48	1508	6.632	3.316		30	328.7	30.43	15.25
	50	1495	6.690	3.345	18		319.6	31.29	15.69
	52	1482	6.748	3.374		30	311.0	32.15	16.12
	54	1469	6.806	3.403	19		302.9	33.01	16.56
	56	1457	6.864	3.432		30	295.3	33.87	16.99
	58	1445	6.922	3.461	20		287.9	34.73	17.43
		1433	6.980	3.490	21		274.4	36.44	18.30
	5	1403	7.125	3.562	22		262.0	38.15	19.17
	10	1375	7.270	3.635	23		250.8	39.87	20.02
	15	1348	7.416	3.708	24		240.5	41.58	20.91
	20	1322	7.563	3.781	25		231.0	43.28	21.77
	25	1298	7.708	3.854	26		222.3	44.98	22.64
	30	1274	7.853	3.927	27		214.2	46.68	23.51
	35	1251	7.998	3.999	28		206.7	48.38	24.37
	40	1228	8.143	4.071	29		199.7	50.07	25.24
	45	1207	8.289	4.145	30		193.2	51.76	26.11
	50	1185	8.432	4.216	31		187.1	53.45	26.97
	55	1166	8.577	4.288	32		181.4	55.13	27.83
5		1146	8.722	4.361	33		176.0	56.80	28.70
	10	1109	9.014	4.507	34		171.0	58.47	29.56
	20	1074	9.304	4.652	35		166.3	60.14	30.42
	30	1042	9.595	4.798	36		161.8	61.80	31.29
	40	1011	9.885	4.942	38		153.6	65.11	33.01
	50	982.7	10.18	5.090	40		146.2	68.40	34.73

Table No. 105.

Length of Ordinates, for 100 Foot Chords, 5 Feet Apart.

Other intermediate ordinates can be found by proportion.

Distances of the Ordinates from the end of the 100 feet Chord.

Ang. of Defl.	Mid. 50 ft.	45 ft.	40 ft.	35 ft.	30 ft.	25 ft.	20 ft.	15 ft.	10 ft.	5 ft.
4	.014	.014	.014	.013	.012	.010	.009	.008	.005	.003
8	.029	.029	.028	.026	.024	.022	.018	.015	.010	.005
12	.043	.043	.041	.038	.037	.033	.028	.022	.015	.008
16	.058	.058	.056	.052	.049	.044	.037	.030	.020	.011
20	.073	.072	.070	.066	.061	.055	.047	.037	.026	.014
24	.087	.086	.083	.077	.074	.066	.056	.045	.031	.017
28	.102	.101	.098	.092	.086	.077	.065	.052	.036	.019
32	.116	.115	.112	.105	.098	.088	.075	.058	.042	.022
36	.131	.130	.126	.119	.110	.099	.084	.066	.047	.024
40	.145	.144	.140	.132	.123	.110	.093	.074	.052	.027
44	.160	.158	.153	.145	.135	.121	.103	.081	.057	.030
48	.174	.172	.167	.158	.147	.132	.112	.088	.062	.033
52	.189	.187	.181	.171	.159	.143	.122	.095	.068	.035
56	.204	.201	.195	.185	.171	.154	.131	.103	.073	.038
1	.219	.216	.209	.198	.183	.164	.140	.111	.078	.041
4	.233	.231	.223	.211	.196	.175	.150	.118	.083	.043
8	.247	.245	.237	.224	.208	.186	.159	.125	.088	.046
12	[illegible]	.260	.252	.237	.220	.196	.168	.133	.094	.049
16	[illegible]	.274	.265	.251	.232	.207	.177	.140	.099	.052
20	[illegible]	.288	.279	.264	.244	.218	.187	.148	.104	.055
24	[illegible]	.303	.293	.277	.256	.229	.197	.155	.109	.057
28	[illegible]	.317	.307	.290	.269	.240	.206	.163	.114	.060
32	[illegible]	.331	.321	.304	.281	.251	.215	.171	.120	.063
36	[illegible]	.345	.335	.317	.293	.262	.224	.178	.125	.066
40	[illegible]	.360	.349	.330	.305	.273	.233	.185	.130	.069
44	[illegible]	.374	.363	.343	.319	.284	.242	.192	.135	.072
48	[illegible]	.389	.377	.356	.330	.295	.251	.200	.141	.075
52	[illegible]	.403	.391	.370	.342	.305	.261	.208	.147	.077
56	[illegible]	.419	.405	.383	.354	.316	.270	.215	.152	.080
2	[illegible]	.432	.419	.397	.366	.327	.280	.222	.157	.083
[illegible]	[illegible]	.446	.433	.409	.379	.338	.289	.230	.162	.086
[illegible]	[illegible]	.461	.447	.425	.391	.349	.298	.237	.167	.088
[illegible]	[illegible]	.475	.461	.437	.403	.360	.308	.245	.173	.091
[illegible]	[illegible]	.490	.475	.450	.415	.371	.317	.252	.178	.093
[illegible]	[illegible]	.504	.489	.463	.428	.382	.326	.260	.183	.096
[illegible]	[illegible]	.518	.503	.476	.440	.393	.334	.267	.188	.099
[illegible]	[illegible]	.533	.517	.489	.453	.404	.346	.275	.194	.102
[illegible]	[illegible]	.547	.531	.502	.465	.415	.355	.282	.199	.104
[illegible]	[illegible]	.562	.545	.516	.477	.425	.364	.289	.204	.107
[illegible]	[illegible]	[illegible]	[illegible]	.529	.489	.436	.373	.297	.209	.110
[illegible]	[illegible]	[illegible]	[illegible]	.542	.501	.447	.382	.304	.214	.112
[illegible]	[illegible]	[illegible]	[illegible]	.555	.513	.458	.391	.312	.219	.115
[illegible]	[illegible]	[illegible]	[illegible]	.569	.526	.469	.401	.319	.225	.118
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.538	.480	.410	.326	.230	.121

[redacted]

ıble No. 105. (Continued.)

Ordinates, for 100 Foot Chords, 5 Feet Apart.

ıte ordinates can be found by proportion.

of the Ordinates from the end of the 100 feet Chord.

40 ft.	35 ft.	30 ft.	25 ft.	20 ft.	15 ft.	10 ft.	5 ft.
1.467	1.389	1.284	1.146	.979	.779	.551	.290
1.502	1.422	1.314	1.173	1.002	.798	.564	.297
1.537	1.454	1.345	1.200	1.026	.816	.576	.304
1.572	1.489	1.375	1.228	1.048	.835	.589	.311
1.607	1.521	1.405	1.255	1.071	.854	.603	.318
1.641	1.553	1.436	1.282	1.095	.872	.616	.324
1.677	1.587	1.467	1.310	1.118	.891	.629	.332
.782	1.657	1.559	1.392	1.188	.946	.668	.351
.886	1.757	1.651	1.474	1.256	1.002	.708	.372
.991	1.857	1.742	1.556	1.326	1.057	.748	.394
1.096	1.957	1.834	1.637	1.396	1.114	.787	.415
.201	2.057	1.926	1.719	1.468	1.170	.827	.436
.306	2.185	2.018	1.802	1.538	1.226	.866	.457
.411	2.285	2.110	1.884	1.609	1.282	.906	.478
.510	2.385	2.203	1.967	1.680	1.339	.946	.499
.621	2.485	2.295	2.049	1.750	1.395	.985	.520
.726	2.585	2.387	2.132	1.820	1.451	1.025	.541
.832	2.685	2.479	2.214	1.891	1.507	1.065	.562
.937	2.785	2.571	2.297	1.961	1.564	1.105	.583
.042	2.884	2.664	2.379	2.031	1.620	1.144	.604
.147	2.984	2.756	2.462	2.102	1.676	1.184	.625
.252	3.084	2.848	2.544	2.172	1.732	1.224	.646
.358	3.184	2.941	2.627	2.243	1.789	1.264	.667
.569	3.384	3.125	2.792	2.384	1.902	1.344	.709
.779	3.584	3.310	2.958	2.525	2.014	1.424	.751
.990	3.784	3.495	3.123	2.666	2.127	1.504	.793
.201	3.984	3.680	3.289	2.808	2.240	1.583	.836
.624	4.386	4.050	3.620	3.093	2.467	1.744	.922
.048	4.789	4.423	3.952	3.379	2.695	1.905	1.008
5.473	5.192	4.798	4.286	3.665	2.924	2.068	1.094
5.898	5.596	5.171	4.622	3.951	3.154	2.232	1.181
6.323	5.999	5.544	4.958	4.239	3.385	2.396	1.268
6.751	6.406	5.922	5.297	4.530	3.619	2.565	1.356
7.179	6.813	6.300	5.637	4.822	3.854	2.733	1.445
7.609	7.222	6.679	5.978	5.115	4.090	2.901	1.535
8.041	7.633	7.060	6.320	5.410	4.327	3.069	1.626
8.474	8.044	7.442	6.664	5.705	4.565	3.238	1.718

responding to angles of deflection, see

.tion of Outer Rail on Curves.

(See also under Table 105A.)

ugal force that a car has moving on a curve row it off the track is counteracted by raising rail or placing the car in such a position ill be an equal force of gravity acting on an ıe in the opposite direction.

s of a curve being known, the proper elevauter rail above the inner one is found by the rmula:

$\div$ 32.2 R, in which E = the elevation, G = ıck, V = velocity in feet per second, and R the curve. This formula is derived from ı ot centrifugal force $V^2 \div R$, and the action n the *inclined* plane 32.2 E $\div$ G.

Table No. 105A.

[illegible] OF RAILS IN FEET.

[illegible]

Table No. 106.

TABLE OF LONG CHORDS.

Deflection Angle.	Radius in Feet	Length of chord in foot required to subtend, the number of stations (100 feet chords between stations) given below.					
		2	3	4	5	6	7
0° 10′	34378.	200.00	300.00	400.00	500.00	599.99	699.98
30′	11459.	200.00	299.99	399.98	499.96	599.93	699.89
1° 0′	5730.	199.99	299 97	399.92	499.85	599.73	699.57
30′	3820.	199.98	299.93	399.83	499.66	599.40	699.04
2°	2865.	199.97	299.88	399.70	499.39	598.93	698.30
30′	2292.	199.95	299.81	399.52	499.05	598.34	697.35
3°	1910.	199.93	299.73	399.32	498.63	597.60	696.17
30′	1637.	199.91	299.63	399.07	498.14	596.74	694.79
4°	1433.	199.88	299.51	398.78	497.57	595.74	693.20
30′	1274.	199.85	299.38	398.46	496.92	594.62	691.41
5°	1146.	199.81	299.24	398.10	496.20	593.36	689.39
30′	1042.	199.77	299 08	397.70	495.40	591.97	687.18
6°	955.4	199.73	298.90	397.26	494.53	590.45	684.75
30′	882.	199.68	298.71	396.79	493.59	588.80	682.11
7°	819.	199.63	298.51	396.28	492.57	587.02	679.29
30′	764.5	199.57	298.29	395.73	491.48	585.11	676.27
8°	716.8	199.51	298.05	395.14	490.31	583.08	673.01
30′	674.6	199.45	297.82	394.52	489.07	580.92	669.60
9°	637.3	199.38	297.56	393.88	487.76	578.66	665.98
30′	603.8	199.32	297.28	393.20	486.88	576.20	662.15
10°	573.7	199.25	296.97	392.43	484.91	573.69	658.13

Long chord = 2 × Radius × sin (½ degree of curvature × number of stations), or = 100 × sin (½ degree of curvature × number of stations) ÷ sin ½ degree of curvature.

Table No. 106A.

EQUIVALENT GRADES FOR EACH DEGREE OF CURVATURE UP TO 20°.

1	degree	equals	1½	feet	per mile	grade.
2	"	"	3	"	"	"
3	"	"	4	"	"	"
4	"	"	6	"	"	"
5	"	"	7	"	"	"
6	"	"	9	"	"	"
7	"	"	11	"	"	"
8	"	"	13	"	"	"
9	"	"	16	"	"	"
10	"	"	19	"	"	"
11	"	"	23	"	"	"
12	"	"	27	"	"	"
13	"	"	31	"	"	"
14	"	"	35	"	"	"
15	"	"	40	"	"	"
16	"	"	45	"	"	"
17	"	"	50	"	"	"
18	"	"	55	"	"	"
19	"	"	60	"	"	"
20	"	"	65	"	"	"

The resistance of curves is very considerable. The less the radius of the curve. and the greater the length of the curved track occupied by the train or car, the greater the resistance.

Table No. 107.

Length of Tangents for a One Degree Curve.

Intersection Angle between Tangents.	Length of each Tangent.	Intersection Angle between Tangents.	Length of each Tangent.	Intersection Angle between Tangents.	Length of each Tangent.	Intersection Angle between Tangents.	Length of each Tangent.
1° ′	50	31° ′	1589	61° ′	3375	91° ′	
1 30	75	31 30	1616	61 30	3409	91 30	
2	100	32	1643	62	3443	92	
2 30	125	32 30	1670	62 30	3477	92 30	
3	150	33	1697	63	3511	93	
3 30	175	33 30	1725	63 30	3546	93 30	
4	200	34	1752	64	3581	94	
4 30	225	34 30	1779	64 30	3616	94 30	
5	250	35	1807	65	3651	95	
5 30	275	35 30	1834	65 30	3686	95 30	
6	300	36	1862	66	3721	96	
6 30	325	36 30	1889	66 30	3757	96 30	
7	350	37	1917	67	3793	97	
7 30	375	37 30	1945	67 30	3829	97 30	
8	401	38	1973	68	3865	98	
8 30	426	38 30	2001	68 30	3902	98 30	
9	451	39	2029	69	3938	99	
9 30	476	39 30	2057	69 30	3975	99 30	
10	501	40	2086	70	4012	100	
10 30	527	40 30	2114	70 30	4049	100 30	
11	552	41	2142	71	4087	101	
11 30	577	41 30	2171	71 30	4125	101 30	
12	602	42	2200	72	4163	102	
12 30	627	42 30	2228	72 30	4201	102 30	
13	653	43	2257	73	4240	103	
13 30	678	43 30	2286	73 30	4279	103 30	
14	704	44	2315	74	4318	104	
14 30	729	44 30	2344	74 30	4357	104 30	
15	754	45	2373	75	4397	105	
15 30	780	45 30	2403	75 30	4437	105 30	
16	805	46	2432	76	4477	106	
16 30	831	46 30	2462	76 30	4517	106 30	
17	856	47	2491	77	4558	107	
17 30	882	47 30	2521	77 30	4599	107 30	
18	908	48	2551	78	4640	108	
18 30	933	48 30	2581	78 30	4681	108 30	
19	959	49	2611	79	4723	109	
19 30	984	49 30	2642	79 30	4766	109 30	
20	1010	50	2672	80	4808	110	
20 30	1036	50 30	2702	80 30	4851	110 30	
21	1062	51	2733	81	4894	111	
21 30	1088	51 30	2764	81 30	4938	111 30	
22	1114	52	2795	82	4981	112	
22 30	1140	52 30	2825	82 30	5025	112 30	
23	1166	53	2857	83	5069	113	
23 30	1192	53 30	2888	83 30	5114	113 30	
24	1218	54	2919	84	5159	114	
24 30	1244	54 30	2951	84 30	5205	114 30	
25	1270	55	2983	85	5250	115	
25 30	1297	55 30	3015	85 30	5297	115 30	
26	1323	56	3047	86	5343	116	
26 30	1349	56 30	3079	86 30	5390	116 30	
27	1376	57	3111	87	5438	117	
27 30	1402	57 30	3143	87 30	5485	117 30	
28	1428	58	3176	88	5533	118	
28 30	1455	58 30	3209	88 30	5582	118 30	
29	1482	59	3242	89	5631	119	
29 30	1509	59 30	3275	89 30	5680	119 30	
30	1535	60	3308	90	5730	120	
30 30	1562	60 30	3342	90 30	5780		

ICK METHOD OF OBTAINING TANGENT DISTANCE.
ractice, when possible, make angles in a survey either even degrees or even degrees + $\frac{1}{4}^{\circ}$ (15′), $\frac{1}{2}^{\circ}$ tc.

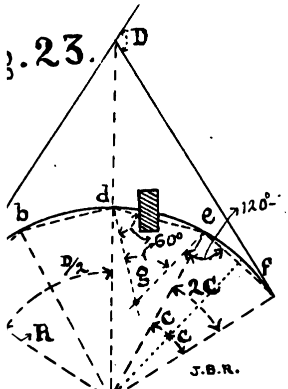
length of tangent or TANGENT DISTANCE can be by formula (5), Table 103, or more quickly and sufficiently accurate for all practical purposes as s:

k in Table No. 107 for length of tangent for a 1° opposite intersection angle—angle in line. Divide ngth of tangent by the degree of curve you desire ate and the quotient will be the tangent distance d. Measure it back on line from intersection and proceed to locate curve, but before so doing re the same distance ahead from intersection and set second tangent point as check on curve loca- If not given in Table find by proportion.

PRACTICAL PROBLEMS

FREQUENTLY ENCOUNTERED IN THE FIELD.

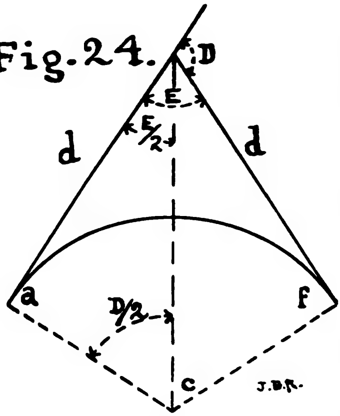
.23.



OBSTACLE ON LINE: Place all stakes as far as d; remove transit to d and with zero on tangent, deflect to the right tangential angle +60° and drive stake at g, a distance from d = the length of chord, as b d, of the curve; next with transit over g with zero on line g d, deflect to the right 60° and drive stake at e a dis- from g = the length of chord of the curve; e will t station on curve from d; next with transit over ect left from line e g, (120° — tangential angle).* f telescope is now on tangent; proceed. Longer s, or lines d g and g e can be used, provided proper ntial angle is used at d and e. Use Table No. 106. vident that a similar equilateral △ can be formed side of curve if more convenient.

gle (120° — T a) in Fig. 23 is not shown correctly by arrows

Fig. 24.



REQUIRED: LENGTH OF TA
having given,
gle E, Fig. 24,
degree of cu
Intersection
D = 180° —
(5) Table No.
Tangent = R
tan. (90° -- ½
use Table No

REQUIRED: NUM-
BER OF CHORD
ing angle E
and radius.
gree of cu
given radius from Table No. 104, then

$$180 - E = \text{number of chords in } 1^\circ \text{ curv}$$

$$(180) -- E) \div 2 = \text{ " " " " } 2^\circ \text{ "}$$

etc., for any other degree curve.. If quotient cc
traction, put in proper sub-chord at one or bo

REQUIRED: RADIUS, knowing the angle E an
ing tangent distance.

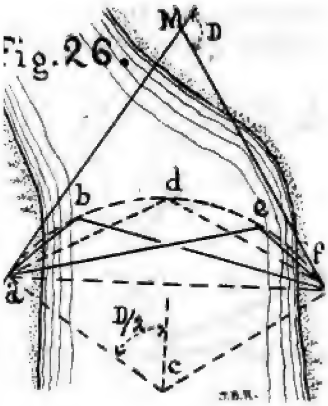
$$\text{Radius} = (\text{tangent distance} \times \tan \frac{E}{2}) \text{ c}$$

See Table No. 102 or 103.

ad 10 or other method, erecting a perpendicular through cutting the bisecting line at O. Produce O P to Q, e point of intersection with the tangent. Then the stance Q a back from Q to the TANGENT POINT will be : $\sqrt{(QP + 2 PO) \times QP}$. Measure a M and it will be e tangent distance d. Set the instrument at a and n in the curve in the usual way and it will pass rough P.

The above equation is obtained because of the relation the similar triangles a QP and a Q B, where P O=O B.

If P is a considerable distauce from O, read compass earing of bisecting line and before moving the instru- ient to O, set it at P and run line P O by compass bear- ig 90° from first read bearing and note point of inter- ection of this line with the string or chain; measure P and produce line to Q, then preceed as before men- oned.



REQUIRED:—TO LOCATE A CURVE WITHOUT A CHAIN, or by intersection angles. Fig. 26.

If a deep river is to be crossed, secure a boat and two transits.

Read angle D.

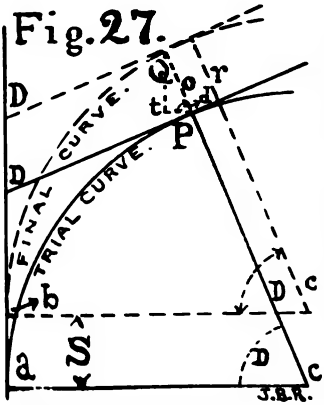
Set transit No. 1 over a with zero on M.

Set transit No. 2 over f with zero on a.

Deflect T_a (tangential angle) to the right om aM with transit No. 1 and have your assistant multaneously deflect the same amount with transit o. 2 from fa to the right. The intersection of the two nes of sight will be the point b on the curve. The an in the boat after getting in line for both instruments in set stake or buoy at b.

Turn proper angles for d, e, etc., to end of curve with ansit No. 1 and at the same time have like operations erformed with transit No. 2, setting stakes or buoys as t b.

Fig. 27.



REQUIRED:—TO PASS A CURVE THROUGH A POINT Q after having located a trial curve through a point P. Fig. 27.

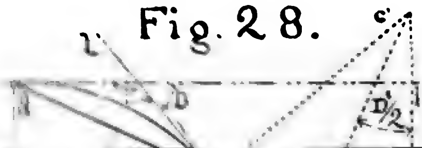
It will have to be moved ahead in the direction of tangent at a, a distance Qt, but Qt=PQ × sin d, while angle d = angle D. ∴ Q t = offset P Q × sin D.

Move point a ahead to b, a distance S = offset × sin D, and the final curve will be found to pass through the point Q.

If trial curve passes through Q, and it is desired to pass final curve through P, move b backwards on tangent to a, a distance = offset P Q × sin D.

In the above it is assumed that offsets P Q = o and offset t are equal.

Fig. 28.



REQUIRED:—TO JOIN TWO PARALLEL LINES by two equal reverse curves.

REQUIRED:—TO JOIN TWO PARALLEL LINES by unequal reverse curves, having given the distance ag, gh and Radius of one curve.

We then have in Fig. 28,

$$ag : gh :: \text{Radius} : \tfrac{1}{2}\, af$$

$$\therefore af = \frac{2 \times \text{Radius} \times gh}{ag}$$

$$gf \text{ (chord required)} = ag - af = ag - \frac{2 \times \text{Radius} \times gh}{ag}$$

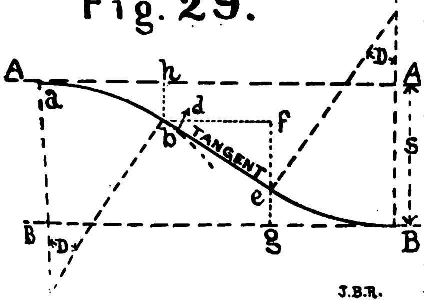
$$R \text{ (radius curve required)} = \frac{ag \times gf}{2\, gh}$$

REQUIRED:—THE ANGLE OF CURVES TO REVRSE between two parallel lines.

In Fig. 28, let S = distance between parallel lines.

We then have $\text{Cos.}{}^*D = \left(\text{Radius} - \frac{S}{2}\right) \div \text{Radius}$.

Fig. 29.



REQUIRED:—TO CROSS FROM ONE LINE TO A PARALLEL LINE, joining them by reverse curves connected by a tangent.

In Fig. 29, let A A and B B represent the parallel lines.

We have angle D = length of curve a b (chord) ÷ degree of curvature, or
= angle d between required tangent (b e) and b f parallel to A A through b.

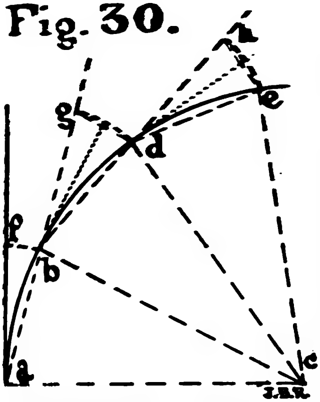
Find tangential distance b h = e g. We then have,

S (distance between A A and B B) — 2 b h = f e;
then tangent required (b e) = f e × cosec d, but cosec d = 1 ÷ sin d.

$\therefore$ b e = f e ÷ sin d.

*D equals angle at centre, or deflection angle × 2.

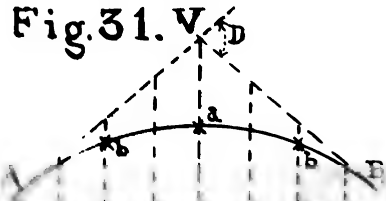
Fig. 30.



REQUIRED:—To lay out a curve without a transit, by chord and tangential deflections.

As shown in Fig. 30, Mark a point f on tangent 100 ft. from a and keeping one end of chain at a, swing the other end until the distance f b = tangential distance as given in Table No. 104 for the degree of curve desired. Next chain ahead from b, 100 ft. to g, putting g in line a b produced. Swing end of chain at g until distance g d = twice f b. Drive a stake at d and proceed to end of the curve in the same manner, making h e, etc. same as distance g d or twice the tangential distance.

Fig. 31.



REQUIRED:—To lay out a curve quickly without a transit.

As shown in Fig. 31, having located A and E at equal dis

engineer would be kept busy all the time re-setting stakes on true curve, while the foreman can easily be taught how to put in such curve when he meets an angle in the line as staked out, and to use good judgment as to the length of tangents. A V and V B need seldom be over 100 ft. in length, and generally 25 or 50 ft. will be sufficient. Should, however, circumstances be such that A V and V B ought to be of considerable length, and more points required on the curve proceed as follows:

Divide the ½ chords A o and B o into such even number of equal parts as may be desired and let N = the number of parts into which each is divided.

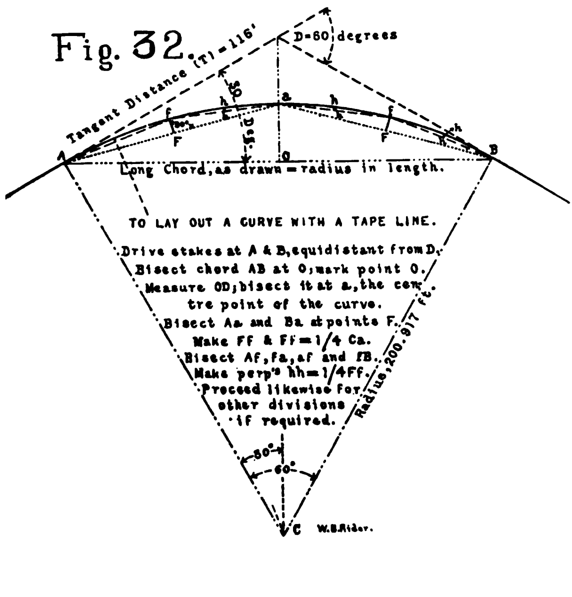
Length of perpendicular from either point

$$\begin{cases} 1 = \dfrac{(N+1)\times(N-1)}{N^2}\times oa \\[2ex] 2 = \dfrac{(N+2)\times(N-2)}{N^2}\times oa \end{cases}$$

&c., etc., to each end of the curve.

Another method (equally rapid) Fig. 32.

Fig. 32.



PAVEMENTS AND ROADS.

For the following complete standard New York State specifications for 6"-Macadam roads, the author is indebted to his friend, Hon. Edward A. Bond, C. E., State Engineer. They are introduced in preference to any from his own practice, because they are more free from clauses relative to local matters and conditions.

Following the specifications, which are, on account of of their length, separated from other mater relative to PAVEMENTS AND ROADS will be found data appertaining to many kinds of popular pavements. (See page 168.)

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[Advertisement......1900] [......Division]

ROAD NO ..

PUBLIC HIGHWAY IMPROVEMENT.

STATE OF NEW YORK.

Chapter 115, Laws of 1898.

SPECIFICATIONS.

WORK TO BE DONE.

The work to be done under these specifications will consist of grading the road to the established grade lines, constructing the necessary drains, ditches and culverts, and laying a six-inch Macadam surface feet wide and all other work necessary for the proper fulfillment of the contract, according to the meaning and intent of the plans and specifications, which plans are a part hereof. The lump sum named in the contract will cover the cost of all work and materials necessary for completion.

The contractor will be required to do all the clearing and grubbing, all excavations and embankments, all levelling, ditching, grading and surfacing, all masonry and stonework, and to furnish all materials for the same. He will be required to build all water-ways, drains and culverts, to clear away all rubbish which may obstruct the road-way or the water-ways. He will be required to protect all fences and to repair or replace the same if they become damaged or destroyed by him or by

employees. In short, he will be required to furnish all the materials, implements and labor required to build and put in complete order for use, the said miles of road. He will be required to remove from the road and from adjoining property all rubbish and surplus materials pertaining to the work, which may have accumulated during its prosecution.

The whole work must be conducted and completed to the satisfaction of the State Engineer and Surveyor.

Grubbing and Clearing.

Where directed by the Engineer all trees, brush and undergrowth shall be removed for the entire area included within the right of way. All fencing material shall be carefully removed and deposited where the Engineer may direct. All stumps and roots shall be grubbed out. All wood and brush thus removed except fencing material shall be burned or removed from the ground so as to do no damage to the adjoining property.

Excavation.

All trees, stumps, brush, sod and roots within the road-bed and on the slopes shall be grubbed up and removed as the Engineer may direct.

The roadway shall be graded throughout its entire length to the width of feet between ditches, and shall conform to the lines and grades, as shown on the plans, and as given by the Engineer.

The side ditches and slopes shall be neatly and truly cut with side slopes of section showed upon plans.

The bottom of ditches shall be cut true to the grades furnished by the Engineer in charge.

All rock, boulders or stumps shall be excavated to a depth of at least six inches below sub-grade. Wherever such rock or boulders have been excavated, a sufficient amount of clear, fresh earth, sand or gravel, approved by the Engineer, shall be furnished and placed so as to make the surface conform to the required sub-grade.

Where clay or rock bottom is encountered it shall be excavated to a uniform depth of three inches below subgrade for the entire width between ditches, and the contractor shall supply and place a sufficient amount of clear loam, *sand or gravel,* approved by the Engineer,

to make the surface of the macadamized portion conform to the required sub-grade and the shoulders beyond the macadamized portion conform to the lines and grades shown on the plans.

If quicksand, fine dust, spongy material or vegetable matter is encountered, it shall be removed to such depth as may be required by the Engineer and replaced by sufficient gravel, sand or loam, approved by the Engineer, to make a firm and stable foundation conforming to the required grade.

Where there is sod, or a hard smooth surface upon the original surface of the ground, it shall be thoroughly broken up and all sod and vegetable matter removed before any embankment is formed thereon, so as to form a proper bond with the new materials.

Embankments shall be formed of clear earth or other materials, satisfactory to the Engineer, and shall be free from vegetable matter or refuse of any kind.

All embankments shall have side slopes as shown upon the plans, but in no case shall slopes be steeper than the "angle of repose" of the material. They shall be constructed in successive layers not exceeding six inches in thickness, and each layer shall be thoroughly rolled with a sectional iron roller weighing not less than two tons. The several sections of such roller to be about three inches wide on their faces and to vary alternately in diameter about three inches. The rolling shall be

.fter the surface of the sub-grade has been properly ped and before any broken stone is applied, the sub-de shall be thoroughly rolled and compacted. This .ng shall be done with a Macadam steam roller nom-ly weighing about ten (10) tons and so built that it ll exert a pressure of about 500 pounds to the linear ı, measured across face of rollers. All hollows and ressions developing during the rolling shall be filled ı material acceptable to the Engineer, and the rolling ll be continued until no depressions can be formed ı the roller.

/hen the sub-grade consists of sand which will not solidate when wet under action of roller, the road-shall be formed to the desired shape and then cov-l with one layer of broken stone, sufficient in quan-for fragments to touch each other. This shall then wet and rolled until consolidated.

Vhen the sub-grade consists of sticky clay too great :xtent to be removed, this shall be formed to the de-:d shape and then covered with about four inches of ıd. This shall then be rolled until consolidated.

No broken stone other than that above mentioned ıll be placed on this sub-grade until the latter has en accepted by the Engineer.

UNDERDRAINS—VITRIFIED PIPE AND POROUS TILE.

Lateral underdrains shall be provided on one or both des of the road, where shown on the plans, to drain ıt and wet portions of the road.

For lengths of 500 feet and over these shall be of five-ıch vitrified tile, first quality, salt glazed, free from listers and cracks, straight and round.

No chipping shall be allowed to insert spigot end into ›ell.

The trench for the drain, two to four feet deep, shall ›e dug to the line and grade furnished by the Engineer. The bottom shall be covered with two or more inches of gravel or gravelly earth and the pipe shall be laid as fast as the trench is ready.

The minimum slope for lateral drains shall be two-tenths of a foot per hundred feet, except in special cases where one-tenth foot per hundred feet may be used with extreme care *in laying*.

Each length of pipe shall be laid with the bell upstream.

The lower one-third of each joint shall be filled with mortar formed of equal parts of American Portland Cement and sand; the upper two-thirds of the bell shall be filled with roll of oakum, pushed in after pipe is laid.

The pipe shall be covered as laid, with six inches or more of gravel or porous earth, placed, packed and tamped around, under and over it, and the trench shall then be filled with the best available material, not clay. During the laying of the pipe, and until the completion of the drain, there shall be kept inside of the drain a close fitting bunch of burlap fastened securely around the end of a four-foot handle; this shall be drawn forward as each joint is added in order to remove any mortar which may project inward at the joints, and to prevent any stones or other obstructions from being left within the drain.

Porous Tile may be used, when so shown on the plans, for the shorter side-drains or for transverse drains; where so used, the tile must be cylindrical, of best quality, well burnt, cherry color, straight, sound and free from cracks. The trench must be fitted to receive the tile by cutting its bottom accurately to grade with a special scoop made to fit the shape of the tile. The ends of the tile shall be laid in close contact, and each joint shall be covered with a piece of burlap twelve

ne size which will produce stone of the sizes herein pecified. They must have on all sides a rough surface btained by fracture. Water-worn pebbles or crushed ebble-stone will not be accepted. Disintegrated and eather-worn stone from the surface of a quarry will ot be accepted. The stone for the different courses must be thoroughly cleaned before crushing and well creened, clean and free from injurious matter of every ature.

KIND AND SIZES OF BROKEN STONE.

The broken stone shall be of two courses. The bottom course will be four inches thick and may consist of rap rock, granite, or any of the harder grades of limestone, broken in sizes varying from a minimum of one nd one-half inches to a maximum of three inches in heir longest dimensions.

The top course shall be two inches thick after rolling nd shall consist of trap rock broken in sizes varying rom a minimum of one inch to a maximum of two nches in their longest dimensions.

Limestone screenings not exceeding one-half inch in ize and free from all dirt shall be added to fill all interstices that cannot be filled by the rolling or compacting f the other stone. Such screenings must be free from arth, sand, loam, or vegetable matter and shall contain all the dust of fracture.

SPREADING AND ROLLING.

After the earth sub-grade has been completed as specified and has passed the inspection of the Engineer, a layer of broken stone of the size and quality hereinbefore specified for the bottom course and of such depth as will when rolled, make a course four inches thick, shall be spread evenly over the prepared subgrade using preferably, spreader-wagons therefor. The roller shall then be rolled first along the edge of the stone lapping upon the shoulder about six inches and going backward and forward several times on each side before rolling the center. The lower course should be rolled about forty times dry, or until the stones do not weave ahead of the roller. Screenings shall then be spread uniformly over the surface to a depth of one-half inch by means of a spreader-wagon, which can be

set to distribute the screenings in any desired qu
over the surface of the roadway. In the abse
such a spreader-wagon, the screenings shall be d
in piles at proper intervals along the side of th
way upon the wings, with plank set on edge a
the stakes to prevent the piles of screenings from
into the ditch. In no case shall the screenin
dumped directly in mass upon the crushed sto
they shall be spread uniformly by spreader-wago
shovels. The screenings shall then be rolled d
they have nearly all disappeared when another
screenings shall be spread and wet with sprink
rolled adding more material if necessary until a
voids are filled, leaving the surface free from scr
in all places.

The top course of stone shall then be
preserving the grade and crown as described for
tom course. Roll the top course ten times dry a
cover it with dry screenings about one inch de
roll ten times dry, after which take a section
[illegible] feet long and saturate with water, followi
the roller. Sufficient amount of water shall be p
fill all of the voids or until it shows on the surfac
proceed with the rolling until a grout has been
of the screenings, stone-dust and water. A
grout has filled all of the voids, it will appea
[illegible]

ection of the road, screenings shall be again spread here required to leave them $\frac{1}{8}$ of an inch deep for a aring surface.

The road shall then be left for forty-eight hours or ger if required until the surface has dried so that roller can pass without sticking, but the road will t be moist enough to pack well. It shall be again led for about ten times dry and then sprinkled twice, lowing with the roller as long as possible without king up the surface. This portion of the road shall en be left to dry for a time varying from two days to week, when it may be opened to travel.

As soon as a section of 100 feet in length shall have en completed in compliance with these specifications nd has dried as described, it shall be thoroughly rinkled at least once a day for thirty days. At any ne during this period, if it is the opinion of the Engi-er that a better result can be obtained by going back the finished work with the roller, this shall be done: rdinarily this should be done every four days, rolling e section about five times. Rainy days shall be de-ted to rolling the finished work.

Method of Carrying on the Work.

The work shall all be carried along together where racticable, the fine grading and rolling of sub-grade eing done just ahead of the lower course of stone and ot exceeding 500 linear feet in advance and as soon as ,000 linear feet of the lower course of stone has been ut on it shall be followed up with the top or finishing ourse, and at no time shall the lower course be over ,000 linear feet in advance of the top of finishing ourse.

The screenings used in both courses of stone shall be elivered in advance of the stone and piled along on the houlders in regular piles containing the required amount necessary to complete the work and shall in no ase be dumped upon the road.

Where it is practicable a driveway shall be main-tained on one side of the improved portion of the road that it may not be necessary to haul material for the top course the full length of the lower course that has been rolled.

Depth and Width of Pavement.

The pavement when completed shall be   feet in width and shall be at least six inches in depth, as is required by the specifications, and of such crown and form of gutter as are shown on plans; and in any case the thickness on the pavement is to be determined on a line at right angles to the grade and crown.

No allowance will be made for any material driven into the sub-grade by rolling, or mistake made by contractor in excavating or fill·ng. The use of a proper roller, rammers or other suitable implements, is to be substituted for that of the steam roller when the Engineer so directs.

Extra Material for Maintenance.

Where called for in the estimate of quantities, in addition to the crushed trap and screenings of limestone used in the work above described, there shall be also provided sufficient quantities of each to form at intervals of 200 feet, piles of crushed trap and of limestone screenings; each pile to be about 3 feet by 6 feet and to be neatly formed at one side of road and to contain about one cubic yard of crushed trap and one-fifth cubic yard of screenings.

Masonry.

All masonry shall be laid in Portland cement mortar as specified below. All stone shall be sound, durable,

or dams neither headers nor stretchers shall extend more than two-thirds through the wall. For these structures this clause takes place of any conflicting preceding clauses.

WIDTH OF BED. Least size equal to the rise, but not less than twelve inches.

CUTTING.

Exposed faces shall be "rock-faced" with projections not more than four inches and with no hollows. The face line of each face stone shall be pitched, and all angles of structures shall be pitched. No dog-holes in face.

JOINTS.

HORIZONTAL. Three-quarters of an inch for six inches.

VERTICAL. Three-quarters of an inch for six inches. Joints to be true and square with face.

BOND.

Bonds of all stones in face, heart and back must be at least eight inches. Headers must come directly over stretchers in next lower course and between headers in next course below and above, and between headers in front and rear of same course.

BACKING.

COURSES. Least thickness six inches, but two courses or more may back one face course. Laid with good bearing on broadest bed.

SIZE OF BACKING STONE. Good-sized, having beds about parallel but not dressed, not less than two square feet surface of bed.

HEADERS. One-fourth of each course placed intermediate. No hollows in face.

JOINTS. All backing stone shall be laid in full beds of mortar, into which small stones shall be pounded to fill all spaces. No grout shall be used.

BOND. All backing stones must break joints and bond eight inches or more.

COPING.

As shown on plans, formed of stone or concrete.

SIZE. Each stone shall be of uniform thickness for continuous lengths of not less than thirty feet. Each stone shall cover full width of wall with length at least equal to width *except when* width exceeds three feet.

CUTTING. Points projecting more than two inches above general surface of top, shall be removed.

JOINTS. All bed and end-joints cut for three-quarter inch joints for full width.

BOND. Each stone shall bond eight inches or more with stone beneath.

BATTER OF WALL. As shown on plans.

ARCHES.

SIZE. Arches formed of second-class masonry shall have ring-stones and sheeting-stones not less than six inches thick at intrados, in regular or irregular broken courses, as may best suit the stone used.

CUTTING. The exterior face shall be dressed to lay within three-quarter inch of the centering. No dog-holes in faces.

JOINTS. The joint must be cut on radial lines with three-quarter inch joints to the full depth shown on plans for the thickness of arch.

BOND. The ring-stones and the sheeting-stones must break joints not less than eight inches.

BACKING. The arch shall be coated on the back with one-half inch No. 1 Portland cement mortar.

Third-Class Masonry.

COURSES. Regular or irregular broken, as may best suit the stones used, forming good substantial rubble masonry. Selected stones shall be used at all angles or

'ERTICAL. Average not more than one inch.

BOND.

Bonds of all stones in face, heart and back must be least six inches.

Headers must come directly over stretchers in next ver course, and between headers in next course below d above and between headers in front and rear of me course.

BACKING.

Projecting points shall be removed from top and ottom beds of all backing stones which shall be laid ith good bearing, on broadest bed, in full bed of motar nto which small stones shall be pounded to fill all paces. No grout will be used.

BOND. All backing stones must break joints and ond six inches or more.

COPING.

As shown on plans formed of stone or first class concrete.

SIZE. Each stone shall be of uniform thickness for continuous lengths of not less than thirty feet. Each stone shall cover full width of wall, except when width exceeds three feet.

CUTTING. Points projecting above general surface of top shall be removed.

JOINTS. Shall average not more than one inch.

BOND. Each stone shall bond six inches or more with stones beneath.

ARCHES.

Arches formed of third class masonry shall have ring-stones and sheeting-stones not less than six inches thick at intrados, in regular or irregular broken courses, as may best suit the stone.

CUTTING. The ring-stones shall be dressed to lay within three-quarter inches of the centering and the sheeting stones shall consist of selected stones of the depth of the arch with good bearings. No dog-holes in faces.

JOINTS. The joints shall be on radial lines for full depth shown on plans for the thickness of arch and shall not exceed three-quarters inch at intrados and one one-half inches *at extrados.*

BOND. The ring-stones and sheeting-stones must break joints not less than six inches.

BACKING. The extrados shall be roughly dressed and filled with mortar in which the stones shall be forced until spaces are completely filled.

PORTLAND CEMENT MORTAR.

The mortor shall be made of best quality of American Portland cement, and clean, sharp sand, in the proportion of three parts of sand to one of cement by volume.

No cement will be used in any part of the masonary until the Engineer shall have approved it. It must be delivered in tight barrels or bags, as the Engineer may direct and thereafter be properly protected from the weather and moisture. Samples of the proposed sand shall be collected by the Engineer and tested at Albany and the Engineer shall direct in what manner it shall be screened and washed, if necessary.

Special directions will be given by the Engineer as to the delivery of cement and as to the time and facilites required for testing the cement and sand previous to use in the work. No cement or sand will be used except in compliance with these directions. All facilities required by the Engineer for securing tests must be provided by the Contractor.

All cement offered for use in any work shall be sampled by an agent of the State Engineer's department

rater test at 125 degrees for twenty-four hours ut "blowing." Portland cement when mixed neat not take its initial set in less than twenty-five :es and when exposed one day in air and six days ter shall withstand a tensile strain of not less than ounds to the square inch, and when mixed in the of three pounds clean, sharp sand to one pound of nt, and exposed one day in air and six days in :, it shall withstand a tensile strain of not less than ounds per square inch.

STONE PAVING.

me paving shall be laid for culvert entrances and ms and outlets and at such other places where it be shown on plans or may be ordered in writing ie Engineer.

ie paving shall be formed of sound, durable, flat, ry stone laid on edge and lengthwise of the flow.

undation for paving shall be formed of sand or el which shall be classed and accounted as lining, which shall not be less than six inches in thickness.

paving shall be formed of stone not less than ve inches deep or as shown on the plans and not than four inches wide and twelve inches long, laid reak joints at least four inches. Each stone must ull depth of the paving as shown on plans and the ts shall be filled with gravel, or with cement mortar specified in the quantity sheet.

he completed paving shall be thoroughly rammed s to bring each stone to a firm bearing on the gravel and and all to a uniform surface.

FLAGGING.

ll flagging shall be of sound, strong, durable stone. less than four inches thick, of a quality satisfactory the Engineer and of such sizes as may be required to n the different culverts, and have a firm bearing of least nine inches back from the face of the support- ; walls. The joints between adjacent stones must t exceed an average width of one inch.

BRIDGES.

Abutments shall be built of masonary as shown on ans. Bridge shall be as shown on the plans.

Existing Cycle Paths and Foot Paths.

Wherever a cycle-path or foot-path shall have been constructed along the road which is to be improved, said path shall be recognized by the Contractor as an existing and important work which shall not be covered, injured or obstructed unless the location is such that such path cannot be wholly avoided.

Culverts Beneath Driveways.

Cast Iron Pipe. Where the side ditches must be carried beneath driveways and road-crossings, culverts shall be of cast iron pipe of sizes and lengths shown on plans.

The pipe may be of second quality, but must be cast in dry sand moulds placed vertically, and truly centered. The iron must be of good quality, uniform in thickness and full strength, coated with coal-pitch varnish mixed with linseed oil to form a firm tough coating.

The joint shall be made by placing a gasket of oakum, and filling hub with mortar formed of equal parts of American Portland cement and clean sharp sand.

The back-filling around the pipes shall be thoroughly tamped under, around and over the pipes and the driveways and road-crossings left in good condition.

Vitrified Pipe. Vitrified pipe shall be furnished and laid for drains as shown on the plans. All pipes shall be first quality, salt glazed, free from blisters and cracks, straight and round. No chipping will be allowed to insert spigot end into bell. All pipe shall be extra thick with extra large bell. All pipes shall be laid true to the lines and grades furnished by the Engineer. Nothing but selected fine material, free from cobbles or large stone shall be placed under or around the pipe, and all material placed under or around the pipe shall be thoroughly tamped with a thin iron tamping bar. All joints shall be made of mortar composed of one part cement to one part clean, coarse sand. The pipe shall be laid on timber foundations if found necssary.

Steel For Bridges.

Steel, except as otherwise provided by these specifications, shall be made by the acid or basic open-hearth *process* and shall be uniform in character; finished *material* shall be clean, smooth, straight, tr

›e, of workmanlike finish and free from defects.
tructural shapes shall be of medium steel.
ivets shall be of soft steel.

IUM STEEL. Test pieces cut from finished material how an ultimate strength of not less than sixty ınd (60,000) pounds per square inch and not more sixty-eight thousand (68,000) pounds per square ın elastic limit of not less than thirty-five thou- 35,000) pounds per square inch, an elongation of ss than twenty-two (22) per cent. in eight (8) inches, reduction of area at the fracture of not less than (40) per cent.

dium steel shall not contain more than five one- redths (05-100) of one per cent. of sulphur.

id steel shall not contain more than six one- redths (06-100) of one per cent. and basic steel not contain more than four one-hundredths (04-100) ıe per cent. of phosphorous. It shall endure ing at eighty degrees (80 deg.) Fahrenheit, one ired and eighty degrees around a circle whose ıeter is equal to the thickness of the test piece out signs of cracking.

›FT STEEL. Test pieces cut from finished material l show an ultimate strength of not less than fifty sand (50,000) pounds per square inch and not more ı fifty-eight thousand (58,000) pounds per square ı, an elastic limit of not less than thirty thousand ›oo) pounds per square inch, an elongation of not than twenty-eight (28) per cent. in eight (8) inches a reduction in area at the fracture of fifty (50) per t.

oft steel shall not contain more than four one- ıdredths (04-100) of one per cent. of sulphur. Acid el shall contain not more than five one-hundredths -100) of one per cent. and basic steel shall contain more than three one-hundredths (03-100) of one per ıt. of phosphorous. It shall endure bending as ecified above for medium steel flat upon itself without ns of cracking.

IRON CASTINGS.

Iron castings shall be made of the best quality of ay iron and shall be free from defects.

Workmanship.

All workmanship shall be first-class in every particular.

Inspection.

All material and workmanship shall be subject at all times to inspection and acceptance or rejection by the State Engineer and Surveyor.

All structural material and workmanship shall comply with the bridge specifications of the State Engineer and Surveyor for the year 1900.

Timber and Planking.

Timber and planking shall be used as shown on the plans and as directed by the Engineer. All timber and planking shall be of a kind shown on the plans, sound and free from sap, shakes, bad knots or decay, and acceptable to the Engineer.

Fencing.

Fence will be constructed on lines given by the Engineer, in accordance with the plans and these specifications.

Posts will be of oak, cedar, chestnut, or other wood acceptable to the Engineer, and six inches square, or seven inches in diameter at the smaller end, if round, after the bark is removed; and six and one-half feet long. They will be matched for guard rails, as shown

brand, delivered upon the work in unbroken cans. The first coat shall be light in color and the second coat black, so as to enable the inspector to see that each coat fully covers all parts.

CLEANING OLD CULVERTS.

Where called for on plans old culverts must be thoroughly cleaned to the satisfaction of the Engineer.

SEEDING SLOPES AND SHOULDERS.

At the time and in a manner directed by the Engineer, the Contractor will seed the shoulders and down-hill slopes with a lawn grass seed, of a kind and quality satisfactory to the Engineer, using not less than one bushel to the acre.

ENGINEER'S ESTIMATE OF QUANTITIES.

...Acres Grubbing and Clearing.
...Cu. yds. Excavation of all kinds (including Earth and Rock) of which....cu. yds. are to be placed in embankment.
...Cu. yds. Broken Stone Macadam Foundation rolled in place.
...Cu. yds. Broken Tap Rock Top rolled in place.
...Cu. yds. extra Broken Tap Rock for maintenance.
...Cu. yds. Limestone Screenings in place.
...Cu. yds. extra Limestone Screenings for maintenance.
...Cu. yds. Second Class Masonry in Cement Mortar.
...Cu. yds. Third Class Masonry in Cement Mortar.
...Cu. yds. Paving.
...Sq. feet...inch Stone Flagging in place.
...Linear feet...inch Cast Iron Pipe (for side drains laid in place complete).
...Linear feet 12 inch Cast Iron Pipe (for Culverts laid in place complete).
....Linear feet 15 inch Cast Iron Pipe (for Culverts laid in place complete).
....Linear feet 18 inch Cast Iron Pipe (for Culverts laid in place complete).
....Linear feet 20 inch Cast Iron Pipe (for Culverts laid in place complete).
....Linear feet 24 inch Cast Iron Pipe (for Culverts laid in place complete).

Linear feet 30 inch Cast Iron Pipe (for Culverts laid in place complete).

Linear feet 5 inch Vitrified Pipe (for underdrains laid in place complete).

Linear feet 12 inch Vitrified Pipe (for Culverts laid in place complete).

Linear feet 15 inch Vitrified Pipe (for Culverts laid in place complete).

Linear feet 18 inch Vitrified Pipe (for Culverts laid in place complete).

Linear feet 20 inch Vitrified Pipe (for Culverts laid in place complete).

Linear feet 24 inch Vitrified Pipe (for Culverts laid in place complete).

Linear feet 30 inch Vitrified Pipe (for Culverts laid in place complete).

Lbs. Steel 6 inch Channel Bars in place.

Lbs. Steel 3 inch I Beams in place.

Lbs. Steel 5 inch I Beams in place.

Lbs. Steel 6 inch I Beams in place.

Lbs. Steel 7 inch I Beams in place.

Lbs. Steel 8 inch I Beams in place.

Lbs. Steel 9 inch I Beams in place.

Lbs. Steel 10 inch I Beams in place.

Lbs. Steel Angles.

Lbs. Wrought Iron Bolts.

Lbs. Spikes and Nails.

ty or parties of the second part do not guarantee the :ectness of the quantities above stated, although e has been taken in preparing same, and that ether these quantities are increased or diminished sum will be paid therefore in excess of the lump n named in the contract, unless the plans or specifiions shall have been changed as provided for in the eneral Clauses" of this specification.

CLAUSES OF GENERAL APPLICATION.

. The plans and specifications are a part of the ıtract and will be held to cover any and all work that ıld be reasonably inferred as needed, taking the two ;ether for a complete and workmanlike job. Work ›wn on the plans and not mentioned in the specificans or vice versa will be done the same as if shown by th, when and where required.

2. All work will be neatly cleaned up on completion, cording to the Engineer's directions, and be left in a at and orderly condition ready for use.

3. The Contractor hereby assumes all risks and ıbilities for accidents or damages that may accrue to ersons or property during the prosecution of the work, y reason of the negligence or carelessness of himself, is agents or employees.

4. The successful bidder shall satisfy the State Engineer, before the contract is awarded to him, that ie has, or will promptly provide suitable and proper men, and all tools and machinery for each of the different kinds of work.

5. Should any work be required, that in the judgment of the State Engineer is not included under these specifications, or not covered by the prices named in the contract, such work shall be done pursuant to the State Engineer's written direction, after the price therefor shall have been agreed upon.

6. The right is reserved to make such changes in the plans or specifications as may, from time to time, appear necessary or desirable, and such changes shall in no wise invalidate this contract. Should such changes be productive of increased cost to the Contractor, a fair and *equitable sum* therefore, to be agreed upon before

such changed work shall have been begun, shall be added to the contract price, and in like manner deductions shall be made.

7. The Contractor shall, without extra compensation, grade a safe, proper and workmanlike connection with all intersecting public or private roads or driveways, according the Engineer's directions.

8. The work shall progress in such manner and at such time as the Engineer may direct.

9. All material which may be rejected shall at once be removed from the vicinity and replaced by material of approved quality.

10. The Contractor shall give his constant personal attention to the work while it is in progress, or he shall place it in charge of a competent and steady foreman who shall have authority to act for the Contractor, and who shall be acceptable to the Engineer. The Contractor shall at all times employ sufficient number of workmen for the proper performance of the several works which he shall prosecute to full completion in the manner and time specified. Any workman whom the Engineer may deem incompetent or unfit for duty shall be at once discharged.

11. Should the Contractor at any time fail or refuse to comply with these specifications, the State Engineer, three days after giving written notice to the Contractor, may purchase necessary materials and employ proper workmen and perform the work; the cost of such materials and labor being deducted from the contract price, as the State Engineer may decide.

12. Wherever the word "Engineer" is used in these specifications, it is understood to mean the State Engineer and Surveyor or his representatives in charge of the work.

Commencement of Work.

Work must be started within ten days after the signing of the contract.

Completion of Work.

All road improvement to be completed by October 15, 1900. If from any cause the entire contract cannot be completed by October 15, the work shall be arranged so that it may be closed down by that date, bringing the top course up within twenty-five feet of the end of the lower course and then left to be completed the following season.

SPECIAL.

'he Contractor will conform to all the provisions of pters 514, 516 and 444 of the Laws of 1897, and pter 567, Laws of 1899, to which special attention of ders is called regarding rates of wages, hours of or and times of payment of employees, and the sub. :ing of contracts.

INSTRUCTIONS TO BIDDERS.

. Bids will be made upon the blank form which lows these specifications; which specifications with : original bid, will be attached to and form a part of e contract.

2. Each bid shall be accompanied by a New York aft or a certified check, payable at sight to the order the State Engineer and Surveyor for 5 per cent of e amount of the proposal; which check shall be held ntil the execution of the contract.

The successful bidder who fails to enter into contract ill forfeit his check.

When the contract has been made, the various checks ill be returned to the bidders who deposited them.

3. The successful bidder must furnish a bond for the ithful performance of the work as provided for by w; such bond to be for the full amount of the contract, nd with sureties and in form satisfactory to and pproved by the State Engineer.

4. Each signature to proposals, guarantees, contracts nd bonds shall be written out in full, and each signa- ure to guarantees, contracts and bonds shall be attested y a witness and shall have affixed an adhesive seal.

5. The place of residence of every bidder, and post fice address, with county and state, must be given ter the signature.

6. One copy of the advertisement as published must : securely attached to, and will be considered as rming a part of, each proposal.

7. All blank spaces in the proposal and bond must filled; and the addition in writing of any condition, nitation or provision will be liable to render the oposals informal and to cause its rejection.

8. No bids will be received after the time set for ening them.

9. The State Engineer and Surveyor reserves the right to reject any or all bids, and to disregard the proposal of any failing contractor.

10. Bidders are invited to be present at the office of the State Engineer and Surveyor in Albany when the bids are opened.

PROPOSAL.

STATE OF NEW YORK.

Public Highway Improvement.

Chapter 115, Laws of 1898.

To the State Engineer and Surveyor of the State of New York:

The undersigned, resident of the .... of ...., County of ...., hereby propose to improve, in accordance with the plans, specifications and form of contract prepared therefor by said State Engineer and Surveyor

....

for the sum of ....

.... dollars

and ...... cents, said sum to be in full compensation for all work, labor and materials required to complete said work according to the meaning and intent of said plans,

Table No. 108.

GRAVITY OF ROAD METAL AND CONSTITUENT
TS OF CERTAIN "METALS" WITH WEIGHTS
PER CUBIC FOOT.

	Specific Gravity.	Average Wgt. per Cubic Ft.	Remarks.
ι	1 to 1.8	87.3	Not used pure.
(Marble)	2.7	168	
e Limestone)			
mon hard		125	
, poor		100	
efuse			Depends on the wood.
pure flint)	2.6	162	
· and loose		70 to 80	
htly packed		82 to 92	
and well packed		90 to 100	
	2.5 to 2.80	166	
rage)	2.60	162	
	2.56 to 2.88	170	
ıpure granite)	2.62 to 2.76	168	
e, trap	2.8 to 3.2	187	
uartz) dry	2.64 to 2.67	90+	Same as Sand.
de. black	3.1 to 3.4	203	
e	2.4 to 2.86	164.4	
Average used on roads.	2.7	168.4	
	2.75 to 3.1	183	
st		80 to 100	Depends on material and space occupied by water
		110 to 130	
l		100 to 120	
pestones	1.9 to 2.5	137	
		20 to 30	Voids about 70 per cent.
	2.66 to 2.8	170	
ommon, pure	2.64 to 2.67	165	
pure quartz	2.64 to 2.67	90+	Depends on voids of 22 to 53 per cent.
es	2.1 to 2.73	151	
nes, good	2.5 to 2.65	162	
ed and black	2.4 to 2.8	162	
ame as Limestone)			Depends on compactness
	2.7 to 2.9	175	
e, steatite	2.65 to 2.8	170	
	1.	62.4	
	2.75 to 3.2	187	
pressed		20 to 30	
	1.	62.375	At 70° Fahr.
ea water	1.026 to 1.03	64.08	
aries)			

Tractive Power of a Horse:—Depends on the foot hold given; his training for the work; his weight and strength. To perform the maximum amount of work it is essential that he be accustomed to the pavement and surroundings.

A good work horse can and will exert in regular work about 20,000 foot-pounds per minute or about $\frac{2}{3}$ of a standard horse power.

Force = Power ÷ Velocity. Assuming the speed while drawing a load over a highway at 200 feet per minute and substituting in the above equation, we have for the CONSTANT TRACTIVE FORCE exerted by a horse in pulling the load, 20,000 ÷ 200 = 100 pounds.........(a) At any other speed within practical limits x, we have

Tractive force in pounds = 20,000 ÷ x.......... (b)

For a short distance, as in ascending a steep pitch, a horse can exert two, three or even more times the power above mentioned. U. S. Dept. Agriculture, Road Enquiry Division tests at Atlanta, showed that a small team of mules could haul 6,000 pounds + wagon up a 10 per cent. short grade. The tractometer indicated a pull of 1,000 pounds, or 500 pounds for each mule. To start a load from rest, requires for an instant, from 3 to 10 times the force necessary to keep the load in motion. The exact amount depends on the condition of pavement under and immediately in front of the wheels, axle friction, flexibility of vehicle, etc. Hence the ne-

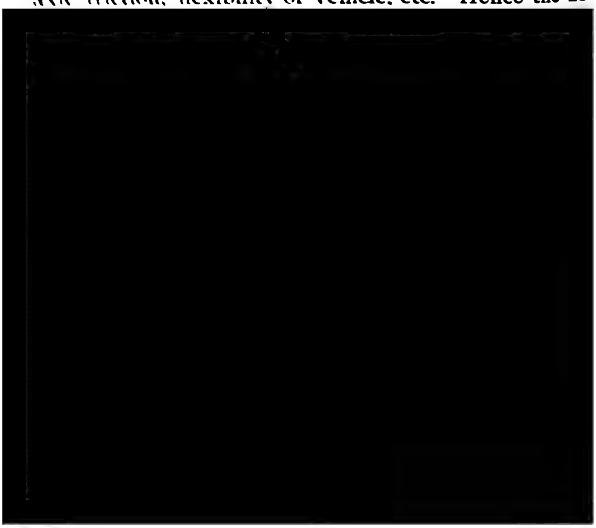


Table No. 109.

PAVEMENT RESISTANCE.

Kind of Pavement	Resistance in Pounds per ton (load + vehicle) moved over pavement.	Resistance compared with good steel track.
Steel track, best, basis of comparison	7.5	1.0
Steel track, average	10-12	1.33-1.6
Asphalt, good	15.	2.0
" poor	25-30	3.3-4
Wood, good	20-30	2.66-4.0
Granite Block, good	35-45	4.66-6.0
" " average	50-80	6.66-10.6
Belgian Block, average about 25 per cent. more than granite block		
Macadam and Telford, good	38-60	5.15-8.0
" " " " fair	60-80	8.0-10.6
" " " " poor	100 or more.	13.3 or more.
Gravel, good	50	6.6
" average	75	10
Earth, dry and hard	60-100	8.0-13.3
" frozen, no ruts, smooth	20-30	2.66-4.0
" fair condition	120-140	16.0-18.6
" ordinary country road	240	32
Cobblestone, good	75	10
" ordinary	150	20
Clay, dry, hard and smooth	100	13.3
Sand, varies depending on moisture contained, etc., average	300	40

Table No. 110 gives the tractive force necessary to draw ONE TON over the best Macadam or Telford road UP various grades. The team is supposed to walk not faster than "natural gait." By proper comparison, using last column of Table No. 109, the tractive force for any other class of pavement is directly given.

Table No. 110.

Rate of Inclination.	Angle with a Level Line. °	′	″	Tractive force necessary to draw one net ton.* Pounds.	Equivalent length of level road in miles.
Level	0	00	00	38	1.00
1 in 500	0	6	53	42	1.19
1 in 100	0	34	23	58	1.52
1 in 80	0	42	58	63	1.66
1 in 60	0	57	18	71	1.87
1 in 50	1	08	16	78	2.05
1 in 40	1	25	57	88	2.30
1 in 30	1	54	37	104	2.73
1 in 25	2	17	26	118	3.10
1 in 20	2	51	21	138	3.63
1 in 15	3	48	51	171	4.50
1 in 10	5	42	58	238	6.26

**Weight includes vehicle.*

Tractive force is independent of the velocity of the vehicle on smooth pavements.

Tractive Resistance on a grade = weight of load × sin of angle of inclination of road to a level line.

The tractive force necessary to overcome a grade = rise per 100' × weight of load ÷ 100'.

The tractive force necessary to pull a load up a grade = (force required to pull the load on a level + (rise per 100' × weight of load) ÷ 100.

Tractive force varies inversely as the diameter of the wheels, and increases with the speed, but not directly as the velocity. Width of tires has little effect on traction when used on a hard road bed, but assist very materially in maintaining a permanently hard and smooth surface.

Brief Notes Relative to Various Pavements.

(Arranged Alphabetically.)

Asphalt.—General Statement—First used with success as a pavement in 1832 in France.

All classes of pavement* have bitumen mineral matter [illegible] water as a base, which is heated, "cooked," until the water is driven off.

To the resultant refined product (too hard for pavement) is added softening material, generally a heavy [illegible] oil, forming a cement which is heated to [illegible] Fine sand heated to 300° is thorough-

ɛam can get little "foot-hold" while it, quicker than ny other class of pavement, gets in a slippery condiion in wet or icy weather.

ABSTRACT OF SPECIFICATIONS:

FOUNDATION:—Should be dry, well-drained and firm.

BASE:—The best is a "hydraulic base" of best conrete 4" to 6" thick, depending on traffic and material f foundation; to this when thoroughly dry should be dded,

BINDER COURSE, of $1\frac{1}{2}$" to 2" thick of best crushed tone, $\frac{1}{2}$" to 1" in size, thoroughly screened, heated and nixed with 20 to 30 gallons per cu. yd. of bituminous aving cement, rolled and rammed to place while hot. The amount of paving cement depends on voids which an be determined by method given on page 185 while it consists of refined asphalt + 15 to 20 per cent. (by weight) of petroleum residum. Next is added,

CUSHION COAT, of properly mixed paving material $\frac{1}{2}$"thick when consolidated. Next is added,

SURFACE COAT, of properly mixed paving material $1\frac{1}{2}$" thick, and finally hydraulic cement is sifted over the urface.

A BITUMINOUS BASE is frequently used in place of oncrete, generally to save expense, and consists of roken stone thoroughly consolidated + about one galon of coal tar or bituminous cement per square yard. n LIGHT CONSTRUCTION a 2" surface coat is placed diectly on base, or a $1\frac{1}{2}$" surface coat when binder course used.

Table No. 111.

ASPHALT PAVEMENTS.

	Per Sq. Yard.	Per 1,000 Feet (1' wide.)	Per Mile (1' wide.)
irst cost depends on location, quality, amount of pavement, competition	\$1.50-\$4.60	\$178-\$511	\$938-\$2,700
ost to maintain (depends on street width, traffic, quality, climatic conditions, thoroughness of maintenance) per year.	7c-15c	7.78-16.66	41-88
ost to maintain Washington, D. C. (with wide pavement, light average traffic) per year	3c	3.33	17.59
ost to maintain London, England per year . . .	15c-35c	16.66-38.88	88.-205
ost to sprinkle and clean per year	1.5c-3c	1.67-3.33	8.80-17.60
alue *of old material* . .	8c-10c	8.89-11.11	46.93-58.66

Heavy traffic, per foot in width, causing a wear of pavement, 3,000 to 12,000. Life of pavement, average [illegible] years. In California, and other places with na[illegible] [illegible] product, the pavement has given poor satisfaction, lasting the few years, generally not exceeding five, of [illegible] construction. It has in many instances been replaced [illegible] brick. It frequently happens, however, that it is too much politics and too little asphalt under poor supervision, that enters the construction and is the real cause of failure.

[illegible] BLOCK:—General Statement—It is not an up-to-date pavement, though much preferable to the cobblestone pavement that it superseded. It is fast being replaced in progressive cities by "stone block," either granite or limestone, depending on the location. It is, at best, nearly as noisy as cobblestone, quite as unsanitary, wears smooth and slippery, is expensive to maintain and clean. Several cities, including South Norwalk, Conn., probably because they could buy cheaply from New York or other cities, have paved certain streets with second hand blocks, and have a pavement [illegible] that those who can, drive around it.

The best place for all second hand paving blocks is in concrete foundation for new pavement.

[illegible] OF SPECIFICATIONS:

FOUNDATION.—Should be dry, well-drained and firm. [illegible] is generally about 6" of sand or fine gravel.

ısing a wear of 1 per cent., 10,000 average. Life of vement depends on foundation, construction, mainnence, but varies from 10 to 20 years.

ʽʽRICK PAVEMENTS:—General Statement—Most popuˑ pavement in small cities and municipalities for ˑeets of maximum traffic. Gives good satisfaction ıen the brick are good vitrified clay or shale, on oper foundation and base. Bricks should be of e commercial size, (varies in different states) average × 4″ × $2\frac{1}{2}$″, lay about 42 to 45 brick to the square yard. uare cornered brick are preferable. A compressive st of 2″ cube ought to show resistance of 10,000 lbs. per uare inch. Transverse strength, 6″ between supports, th knife edge centre load ought to show a Modulus of upture of at least 1,500 pounds according to the folwing formula,

Modulus of Rupture in pounds per square inch $= \frac{3}{2} \times \frac{W l}{b \times d^2}$ in which W = breaking load aplied at centre, l = the length, b = the breadth, and = the depth of brick in inches. A good brick will ot absorb, when broken in centre over 1 or 2 per cent. f water in an over night test, but a brick otherwise ;ood ought not to be condemned on account of an aborption of 5 per cent. Traffic over brick pavement aid on cushion coat in freezing weather causes a rumbing "hollow" sound that is annoying to both resident ınd user of street. The moisture on the sand freezing, :ends to expand the cushion coat which when thawed ʾut occupies less space, leaving a layer of air, so to speak, under the brick. Filled foundation when not properly puddled or rolled, will also settle away from :he concrete, producing the same effect. Good practice ˑequires that grade from centre to side of street should ɔot be too great, and seldom over 6″ to 8″ for a 50 street, making top of curb on same level as centre of ˑoadway. Nothing looks worse than a "warped street ıurface," made so by change of grade from centre to ide, and too frequently done to accommodate some inlividual property-holders sidewalk or a Street Railway ʾo., and forced upon the Engineer and Contractor by a treet Committee, making an otherwise good pavement

almost impassible in certain places in winter, on account of steep side grade. Part of High street, Pottstown, Pa. furnishes an example of such a warped surface.

ABSTRACT OF SPECIFICATIONS:

FOUNDATION, ought to be dry, well-drained and firm.

BASE, ought to be of concrete, 4" to 6" thick, depending on traffic and character of foundation.

CUSHION COAT, generally of ¾" to 1½" of clean sharp sand

BRICKS, as stated on preceding page.

After pavement is well rammed to place, joints should be filled with coal tar or asphalt, though the most frequent practice is to fill or slush the joints with hydraulic cement grout. The slightest jar soon loosens the bond of the cement, and the pavement is no longer impervious, therefore not sanitary. Keeping travel off the pavement for a few days after completion does not insure cement bond not breaking. Sand joints are also used.

Table No. 113.

BRICK PAVEMENTS.

	Per Sq. Yard.	Per 1,000 Feet (1' wide.)	Per Mile (1' wide.)
First cost* on sand foundation, ...	$1.00 to $3.00	$111-$333	$587.-$1760
Cost to maintain per year,	4c to 6c	4.44-6.67	23.44-35.17
Cost to clean and sprinkle per year, ...	3c to 6c	3.33-6.67	17.60-35.17

Value of old material = its value for concrete. When broken stone is expensive and old brick cheap or on hand, they can be used for concrete. Tons traffic per foot in width causing a wear of 1 per cent. 5,000 to 20,000, depending upon whether base is of sand or concrete, character of foundation, whether travel is forced into one position by car tracks, etc. Life of pavement, 5 to 15 years, but at least 12 when it is properly constructed of good material.

*Many brick pavements on sand base have been constructed for less than $1.00 per square yard, under the favorable conditions and price of brick as in Illinois. $1.65 is a fair price under average conditions, divided about as follows: Brick 54c, ($12 per M.); Freight and cartage, 40c; Sand foundation at $1.00 per cubic yard, 17c; Labor and other items 39c; Profit, 10 per cent., total of $1.65 exclusive of grading. Adding $.70 per sq.yd. for difference in cost of sand and concrete base we have $2.35 as fair average price for BRICK PAVEMENT ON CONCRETE BASE. Local conditions will vary this figure, or when contractors are "hungry for work" and bid in fair competition without collusion, the price frequently drops to $1.90 or $2.00, including the necessary excavation and removal. In such instances the profit is seldom commensurate with the time, trouble, expense, and annoyance involved in *"putting down"* the pavement in the average small municipality *where those* that know nothing about the paving business generally *"line the sidewalk,"* watch operations and condemn *job from* start to finish, but have nothing to say after complet

ARCOAL REFUSE:—In Southern Louisiana and else-
e, refuse from charcoal manufacture is used as a
d metal," though it ought not to be classed as
However, if it was not used, nothing would be
place, and it is therefore to be commended. It
es a fair surface for a short time, keeping travel
of the mud. Its cost is generally simply the cost to
er and spread.

HERT:—(Impure Hornstone)—Is used with fair suc-
in parts of Alabama, (average cost $1.00 per cubic
d) and with good success for country roads in North
stern Arkansas, where roads made of it are never
y muddy, and seldom dusty. It makes a good hard
face. In certain other places it gives less satisfac-
n on account of its variable quality. As a rule with
eap gravel, a gravel "wearing coat," at least, is to
prefered, though chert can be used to advantage
r the lower courses.

CINDERS are used with considerable success for cycle
aths, light traffic, drives, etc., in all sections of the coun-
ry, but cannot be classed as a "road metal."

CLAY SHALE:—Used as a "road metal" on suburban
and light traffic roads, but as a rule it is too "sticky" to
give satisfaction.

CLAY AND SAND MIXED:—Has been used with marked
success as "road metal" for roads of light traffic. The
clay should be only in sufficient quantity to act as a
binder. The roads of Millville, New Jersey are a splen-
lid example. Bartow and other places in Florida have
also been successful.

COBBLESTONE PAVEMENT:—This pavement was up-to-
late in 1657 when it was first introduced into N. Y. city,
ut few Engineers would think of advising its adoption
early two and a half centuries afterwards, though such
avements are still to be found in use, even in the
orough of Brooklyn, N. Y.

GRAVEL:—A well-constructed gravel road, made of
od material, properly drained and maintained, will
ve better satisfaction in many localities, than a
acadam or Telford road made entirely of local stone.

BSTRACT OF SPECIFICATIONS, 6″ Road:

A SIX-INCH ROAD should not be placed on any but the
st of *dry foundations.* All general clauses relative

to Macadam road construction, herein given, apply equally well to gravel roads; in fact there ought to be little difference in the method of construction, except that in the one case broken stone is used while in the other gravel is the "road metal."

SHOULDERS ought to be at least 3' wide on top, except in depressions where new road bed is above the old surface; here they should be increased to such a width that travel will not be dangerous.

CUTS AND FILLS:—Do not have them balance each other, but have cuts at least 15 per cent. greater than fills. Where possible, have each cut = adjacent fill + 15 per cent., saving haul of material to distant points; if the material excavated contains boulders or rock, this allowance of 15 per cent. will as a rule be sufficient to provide for shrinkage and increased width of shoulders in the depressions.

It is useless, however, to give a set rule for shrinkage; it should be left to the judgment of the local Engineer or Contractor, who has handled the specific material under consideration. For quick method to compute road embankments, see under "EMBANKMENTS."

BOTTOM COURSE:—Should not contain less than 80 per cent. of clean sharp gravel from the size of a pea to 2½ inches in diameter, with the smaller sizes predominating; remainder should be of good quality bind-

», in part, avoid this it is good practice to crown the ntre during construction at least 3" more than the tablished section; after a year's use road will general- be of shape designed.

8 AND 10 INCH ROADS:—Construct middle course and p metal covering same as 6" road. Bottom course can of larger gravel or even stone, hand placed as in Tel- rd construction. Round stone should be broken, as ley will not properly pack so as to give an even and gid bearing; again medium size and small round one "crawl" by the action of frost, to the surface. No one that is effected by frost should be used in any art or course of road.

COST OF GRAVEL ROADS:—Connecticut, State 8" Gravel oads, 16' wide between shoulders, have been construc- ed under the supervision of William B. Rider, C. E., nd the author for 31 and 38 cents per lineal foot (separ- te contracts and contractors) exclusive of cost for sur- eys, plans and supervision.

These prices included all gravel, cost in bank nominal, about one cent per lineal foot of road) cartage average one mile; about 2,500 cubic yards of earth and 100 cubic yards of granite rock excavation per mile; all excavated material was used in construction with aver- age of under 500 foot haul.

The above prices are not cited as criterion, but to show how low certain contractors will bid, when they do not fully comprehend the difficulties to be encoun- tered in shallow cut and fill work on old hard road sur- face. A fair price for the work would have been be- tween 50 and 60 cents per lineal foot, and there is reason to believe that it cost this amount.

Table No. 114.

8"* GRAVEL ROADS.

	Per Sq. Yard.	Per 1000 feet (1' wide.)	Per Mile (1' wide.)
First cost 8" x 16' wide, 50c per lineal foot . . .	\$.28	\$31.25	\$165.00
Cost to maintain per year, under average conditions	1c	1.11	5.866

Gravel roads are not, as a rule, constructed in localities where it is practicable to clean and sprinkle for reasonable cost; except when repaired; though top metal would pull out less if road was sprinkled.

See line 22, page 189.

*For 10" Roads add for cost of lower course. Excavation same in all cases or can be made so, by raising grade line of road.

For 6" Roads deduct ¼ cost for gravel in place.

Value of old material = $\frac{2}{3}$ value of new less cost to screen. Material will waste about $\frac{1}{3}$ in screening out the worn out top metal, dust and foreign matter.

Tons traffic per foot in width causing a wear of 1 per cent., depends upon the width of road, foundation, construction, quality of material, and TIRE WIDTH.

Gravel roads constructed under the authors supervision, have sustained an average daily traffic of 200 vehicles per day with average load of not far from $\frac{3}{4}$ ton (with frequent loads of two to three tons) for two years without repairs, except to the wearing coat. To repair or rather replace such of the wearing coat as had been ground to dust, true up the shoulders with road machine, and keep the gutters clean, has cost less than $100 per annum per mile.

All worn out TOP METAL, dust and foreign matter should be swept off the road before placing new road metal or it will not properly bind to old surface. It is better to "pick up" the cleaned road surface about $\frac{1}{2}$" deep before placing top metal.

LIFE OF GRAVEL ROAD will depend entirely upon how well it is maintained for the traffic it sustains. If top metal is regularly replaced as above, and foundation is firm and well drained, it ought to last 20 years or more.

GRANITE BLOCK.—Best pavement for maximum city traffic.

FOUNDATION ought to be dry and well drained.

Table No. 115.

GRANITE BLOCK.

	Per Sq. Yard	Per 1.000 feet (1' wide)	Per Mile (1' wide)
: cost on sand foundan*	$1.50-$4.00	$167.-$444	$880.-$2347
to maintain per year	2c	2.22	11.73
to clean and sprinkle r year	10c	11.10	58.65
ie of old material, genally about	80c	89.	469.

ons traffic per foot in width, causing wear of 1 per t., 60000 to 80000 tons. Life of pavement, 15 to 30 rs, when on concrete; life when on sand 10 to 20 years.

THER BLOCK:—LIMESTONE and SANDSTONE are the st common. Sandstone blocks have given good satiction in many of the cities of the central states, but a rule, limestone block has not given the best of sataction.

Pavements of either stone are constructed as given der Granite Block, but the blocks are generally of eater dimensions.

Table No. 116.

SANDSTONE BLOCK.

	Per Sq. Yard.	Per 1,000 feet (1' wide.)	Per Mile (1' wide.)
irst cost	$1.25-$3.00	$139.-$333	$733.-1760.
ost to maintain per year	1½c-3c	1.66-3.33	8.80-$17.60
ost to clean and sprinkle per year	10c	11.11	58.66
alue of old material generally about	60c	66.66	351.96

Tons traffic per foot in width causing wear of 1 per ent., depends on quality of stone which varies, but ught to be when on concrete base, at least 50,000.

Life of pavement, 7 to 18 years.

MACADAM ROADS—General Statement:—Nearly a cenury ago, John Louden Macadam began his experiments n "stone road" making in Scotland; later at Bristol, as County Magistrate and Surveyor, marked success rowned his efforts at road construction. Little change as been made in the general principles he established. Until the last decade, authorities in the States have een slow to adopt "stone roads."

Essex County, New Jersey, however, especially in nd around Orange, had a very complete system of ELFORD roads and avenues twenty years ago, many of hich were constructed under the supervision of James Owen, C. E., of Montclair.

*For light concrete construction add 70c per square yard to rice given.

They have stood the test of time and traffic, under trying conditions of, in many cases, wet clay, and quick sand sub-soil. That they were well constructed the author can testify, having had to dig through many miles of them during the construction of the Orange, N. J. water works. (William B. Rider, C. E., Ch. Engr.) in 1883-4.

Though such Telford roads have their staunch friends, and the author is one of them, it must be admitted that no pavement is receiving such popular attention and approval, especially in the Eastern States as "Macadam."

Where stone roads are adapted to the traffic and are not approved, the reason can often be traced to un-systematic methods, un-scientific plans, poor supervision, construction or material.

Many who have sense enough not to jump out of a boat and expect to remain on the surface, expect crushed stone when spread or thrown in the mud a few inches deep to stay on top. Such men in charge of public highways, as officials or employees, are not few. It is quite true that any common road bed is improved for the time being by a dressing of crushed stone, but unless the foundation and sub road bed are of gravel or other porous soil, no permanent improvement is made and the money is wasted soon after a few heavy rains, or a thaw

r the next experiment, which is generally the same e, with slight variations in details. In no branch of blic or quasi public work is so much money wasted in road construction, and especially is this true in the e of crushed stone.

PRACTICAL DATA, SPECIFIC GRAVITY: See Table No.)—The importance of high specific gravity of "road etal," especially that of the top or wearing coat cannot over-estimated. In general, other things being ual, each one-tenth reduction in specific gravity reces the value of the stone as a road metal 10 per cent. In other words best trap rock, specific gravity of 3.0 3.1, is worth 20 per cent. more money, as a road etal, than a poor trap of specific gravity of 2.8 to 2.9. about 20 per cent. more than the best limestone.

A limestone of high specific gravity is preferable to a w grade trap, but not to a high grade trap. The fact at the limestone will grind up and make its own biner is sufficient reason for using a high grade trap + a nder (if it can be had at reasonable cost) for wearing oat, at least. Again, limestone mud is claimed by any to be much more injurious to the varnish and aint on vehicles.

VOIDS IN ROAD METAL: See Table No. 119—Equally nportant with specific gravity is the amount of voids n the road metal. They can both be determined, on or near the work quickly, by the following crude method, requently used by the author or his assistants when nconvenient to send sample and have the work done in his laboratory.

Secure a quart, gallon or other tight measure, (a water pail will answer) counterbalance it on scales, then

1st. Fill measure even full of water, weigh, call weight.. (a)

2nd. Empty the water.

3rd. Fill measure even full of road metal, packed, so as to not leave too many voids around sides of measure, call weight.. (b)

4th. Pour in water until voids between stone are filled, call weight of stone + water now in measure.... (c)

We then have weight of water filling voids = c − b; call this weight.. (d)

∴ per cent. of voids = d ÷ a = (c—b) ÷ a........ (e)

Weight of water displaced by road metal = a—d; call this weight.. (f)

∴ *specific gravity of road metal* = b ÷ f.

If voids in road as constructed are desired, take t one square foot of same, put it in tight box one fo square in area, and pack to same depth exactly as road; fill with water, weigh, etc., as before.

To get same height in box and road, use straight edg across top of road metal in both instances.

EXAMPLE, from authors practice, Sept. 4, 1900.

On hand in "country store," gallon measure, commo scales, sample road metal as taken from one of th wagons delivering same.

	Pounds
Gallon measure counterbalanced on scales, indicated weight........................	0.00
(a) Weight measure full water, 8 lbs. 5½ oz.*=	8.3216
(b) " " " stone, 13 lbs. 15½ oz.=	13.96875
(c) " " " " + water (in voids,) 17 lbs. 12½ oz.=.................	17.78125
(d) Weight water filling voids = c—b=......	3.8125
(e) Per cent. of voids = d ÷ a = 46 per cent. nearly.	
(f) Weight of water displaced by stone=a—d=	4.509
(g) Specific Gravity of stone = b ÷ f = 3.1 nearly, or above the standard 3.0 called for in the contract.	

AMOUNT OF VOIDS, should be reduced to a minimum in the lower courses, and to less than 5 or 8 per cent. in the top metal. The object being to form a road bed

No Macadam road will be a success if bottom of gutter is higher than the bottom of road bed, unless independent drains are laid below, and for the purpose of keeping it and foundation from being soaked or filled with water, unless perchance the foundation is very porous, and of itself well drained.

VOIDS, HOW REDUCED IN PRACTICE:—If the specifications herein given, relative to 6″ Macadam roads are followed, so far as rolling, etc. of stone is concerned, in practice the procedure and results will be about as follows.

6″ in depth of $2\frac{1}{2}$″ stone placed loose, for first course, contain an average of 50 per cent. voids, and by proper rolling, etc., will reduce to 4″ in depth of various sizes of stone from dust to $2\frac{1}{2}$″ with size from $1\frac{1}{4}$″ to $2\frac{1}{2}$″ predominating and making a volume of stone containing 25 per cent. voids. In other words, rolling will reduce the amount of voids one half.

To this volume, can now be added, by proper rolling, sprinkling, etc., about $\frac{1}{2}$″, average, in depth of $\frac{7}{8}$″ to $\frac{1}{2}$″ screenings + quarry dust, without increasing the volume, but making a finished lower course, 4″ in depth, with less than an average of 15 per cent. voids.

On this can now be placed 3″ in depth of loose $1\frac{1}{4}$″ to $1\frac{1}{2}$″ stone, which will roll to 2″ in depth; to this 2″ rolled course can be added by proper rolling, sprinkling, etc., about $\frac{1}{2}$″ of $\frac{3}{4}$″ MIXED SCREENINGS, (see Table No. 117 without increasing the volume and making a course 2″ in depth with less than 15 per cent. of voids.

Adding to this a top dressing of fine screenings mixed with sufficient "binder," if necessary, roll, etc., and voids in top portion will be reduced to from 5 to 8 per cent., and be as near "water tight" as it will be possible to make it, without using so much "binder" that, in wet weather it would stick to the wheels of vehicles, pulling out at the same time "metal" from the top course. It will be noted that the aggregate depth of stone necessary to make the SIX INCH ROAD is TEN INCHES; therefore under ordinary conditions, the amount of stone required to construct a SIX INCH ROAD = 1.66 × cubical contents of the finished road. For the specific amount in loose cubic yards of each size of stone for 4″, 6″ and 8″ roads, together with other practical data, see *Table No. 118.*

[illegible] voids in top course [illegible] when proper binder is added, the [illegible] with success what is called by certain [illegible] containing all the [illegible] line of fracture." A [illegible] is taken from his files [illegible]

Table No. [illegible]

[illegible] 1900. Kind [illegible] Fort Lee, N. J. [illegible] Specific gravity, 3.056

[illegible]

[illegible]	[illegible] grams.	
[illegible]	[illegible]	"
[illegible]	[illegible]	"
[illegible]	[illegible]	"
[illegible]	[illegible]	"
[illegible]	[illegible]	"
[illegible]	[illegible]	"
[illegible]	[illegible]	"

:efore to use a binder in order that it, the trap, cemented before it is practically ground to As to its amount, the author hesitates to name cnowing well that too much will ruin the best iile too little means that the top course will not ar "water tight" as it is possible to make it. es itself into a question of good judgment in se, depending on the quality of stone, kind of :., but as a general statement, it can be said it to 20 per cent. of the volume of top or wearing 'he best plan to follow is to take the first few . feet of road ready for top metal and add it + nount of binder, watch the results and if more is add it, and use the information gained in con- g the remainder of the road.

shrinks, in very dry weather, about one-fifth in

Macadam or any other road using a "binder" heretore be sprinkled in DRY WEATHER to such it as will keep the "binder" uniform in volume; se it ceases to be a binder and the top metal oose from it.

is fact, lack of proper sprinkling,* can be attri- ie loose stone on the surface of many roads; also tofore stated, the amount of binder should not great that it will stick to wheels etc. in wet :; in so doing it pulls out the metal; leaving it ı the surface.

ON OF ROAD:—Do not crown your road too much; oot is ample in most cases for slope from centre of road bed or shoulders. Have gutter when ɜ, as on suburban work, at least one foot below houlder and two feet if possible.

S AND MACHINERY;—Do not attempt to construct ım roads without use of proper tools and machin- t cannot be done and done well. Steam roller, achines, etc., (see part 2) are as essential to good

[illegible] explains itself. [illegible] construct[illegible] [illegible] is inte[illegible] [illegible] and in[illegible] [illegible] engine[illegible] [illegible]

Table No. 3

[illegible]

ST OF MACADAM ROADS:—Exclusive of grading and quarry within two miles of work, or stone delivered in same distance of work, the average cost to construct under the supervision of the author, has been about 5 per cubic yard of finished road. Or we have,

For a 8" road,	16 feet wide,	$1.25 per lineal foot.
" " 6"	" " " "	.97 " " "
" " 4"	" " " "	.70 " " "

Under favorable conditious with quarry adjacent to the work and stone cheap, as for instance, near any of the "Orange Mountain quarries from Paterson southerly, through upper Montclair, Montclair, West Orange, etc. to Milburn. N. J., the price per lineal foot has at times been as low as 75 to 80 cents for 8" road, and 50 cents for 6" road. The average cost of Macadam roads in New Jersey for the year 1900 was slightly in excess of $1.00 per lineal foot.

GRADING:—Where the old road surface is followed, the cost is from 30 to 60 per cent. of the cost of the Macadam in place. It depends entirely on whether the contractor or municipality doing the work is equipped with modern ROAD MACHINES and other up-to-date road machinery, (see part 2) or depends on a pick, shovel, garden plough and crowbar—and borrowing from willing and unwilling residents along the route.

COST TO MAINTAIN:—Depends on method of construction and foundation; quality of stone; amount of travel and climatic conditions. It must be remembered in comparing the cost of repairing an improved Macadam or Telford road with the cost to repair the "old road" over the same distance, that not only is the average weight per load carried over the new road nearly if not quite twice as great, but such a road attracts traffic away from other or parallel roads resulting in many cases two, three and even more times the ton-miles o traffic that was carried over the old unimproved road.

Stone Roads, (Telford) in and around Orange, N. J., have been used 5 to 15 years without repairs; notably parts of the parallel avenues crossing over Orange Mountain, where they are grades of 5 and 8 per cent. If properly constructed, and road is wide enough to not drive traffic in a rut, the actual wear will not exceed an average of ½" per year, or about *12 to 15 cubic yards per mile* for a TRAP ROCK SURFACE.

Centrally located electric or other track drives t fic into a rut on either side, as a rule, and in such ca the repairs will be two, three or more times as gr while the Macadam surface cannot be kept in pro repair without monthly or bi-monthly attention. M cipalities are fast beginning to realize that transpo tion companies occupying highways ought to pay t share of the expense of maintaining them.

Before making repairs, all worn out stone, dust, refuse should be swept and washed from the surf and about ½" to 1" of road metal "picked up" so a insure proper consolidation. Ruts and holes shoul repaired from time to time as they appear.

For life of pavement see Telford Roads.

Telford Roads, 12" Road:—Excavate to one below finished grade. Have all properly drained foundation firm. Place by hand irregular sh stone, not rounding, (of any durable nature, and as are not effected by frost) about 8" deep x 6" t wide. Set same on their broadest side, with points and in rows at right angles to direction of tr Knock off the points with a hammer, and fill spaces tween the large stone with the chips and others if essary. Bring surface of layer to within 6" or 4" of surface of finished road, this depends on total dep Telford. Construct remainder as in Macadam building.

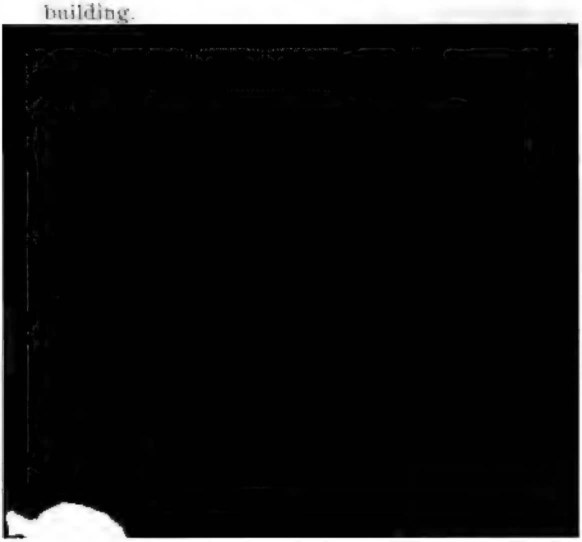


Table No. 119.

WEIGHT OF ROAD METAL ETC., CONTAINING VOIDS. (Original.)

Voids in per cent. of total volume.	Spec. Grav. 1.0 Water at 70° Fahr. Cu. yard.	Cu. foot.	Specific Gravity 2.2 Cu. yard.	Cu. foot.	Specific Gravity 2.3 Cu. yard.	Cu. foot.	Specific Gravity 2.4 Cu. yard.	Cu. foot.	Specific Gravity 2.5 Cu. yard.	Cu. foot.	Specific Gravity 2.6. Cu. yard.	Cu. foot.	Specific Gravity 2.7. Cu. yard.	Cu. foot.	Specific Gravity 2.8. Cu. yard.	Cu. foot.	Specific Gravity 2.9. Cu. yard.	Cu. foot.	Specific Gravity 3.0. Cu. yard.	Cu. foot.	Specific Gravity 3.1. Cu. yard.	Cu. foot.
0	1684.1	62.372	3704.9	137.2	3873.4	143.5	4041.8	149.7	4210.2	155.9	4378.6	162.2	4547.	168.4	4715.4	174.6	4883.8	180.9	5052.2	187.1	5220.6	193.4
5	1599.9	59.3	3519.7	130.3	3679.7	136.3	3839.7	142.2	3999.7	148.1	4159.6	154.1	4319.6	160.	4479.6	165.9	4639.6	171.9	4799.6	177.8	4959.6	183.7
10	1515.7	56.1	3334.4	123.5	3486.1	129.2	3637.6	134.7	3789.2	140.3	3940.7	146.	4092.3	151.6	4243.8	157.2	4395.4	162.8	4547.	168.4	4698.5	174.1
15	1431.5	53.	3149.	116.7	3292.4	121.9	3435.5	127.2	3578.7	132.5	3721.8	137.8	3864.9	143.2	4008.1	148.5	4151.2	153.8	4294.4	159.1	4437.5	164.4
20	1347.3	49.9	2963.9	109.8	3098.7	114.8	3233.4	119.8	3368.2	124.7	3502.9	129.7	3637.6	134.8	3772.3	139.7	3907.	144.7	4041.8	149.7	4176.5	154.7
25	1263.	46.8	2778.	102.9	2905.1	107.6	3031.3	112.3	3157.7	116.9	3283.9	121.6	3410.2	126.3	3536.5	131.	3662.9	135.7	3789.2	140.3	3915.4	145.1
30	1178.8	43.7	2593.	96.	2711.4	100.5	2829.3	104.8	2947.1	109.1	3065.	113.5	3182.9	117.9	3300.8	122.3	3418.7	126.6	3536.5	131.	3654.4	135.4
35	1094.6	40.5	2408.2	89.2	2517.7	93.3	2627.2	97.3	2736.6	101.3	2846.	105.4	2955.5	109.5	3065.	113.5	3174.5	117.6	3283.9	121.6	3393.4	125.7
36	1077.8	39.9	2371.	87.8	2479.	91.8	2586.7	95.8	2694.5	99.8	2802.2	103.8	2910.1	107.8	3017.7	111.8	3125.6	115.8	3233.4	119.8	3341.2	123.8
37	1061.	39.3	2334.	86.4	2440.3	90.4	2546.3	94.3	2652.4	98.2	2758.4	102.2	2864.6	106.1	2970.6	110.	3076.8	114.	3182.9	117.9	3289.	121.9
38	1044.1	38.7	2297.	85.1	2401.6	89.	2505.9	92.8	2610.3	96.7	2714.6	100.5	2819.1	104.4	2923.4	108.3	3028.	112.1	3132.4	116.1	3236.8	120.
39	1027.3	38.	2260.	83.7	2362.9	87.5	2465.5	91.3	2568.2	95.1	2670.8	98.9	2773.7	102.7	2876.4	106.5	2979.1	110.3	3081.8	114.2	3184.6	118.1
40	1010.4	37.4	2223.	82.3	2324.1	86.1	2425.1	89.8	2526.1	93.6	2627.	97.3	2728.2	101.	2829.2	104.8	2930.3	108.5	3031.3	112.3	3132.4	116.1
41	993.6	36.8	2185.9	81.	2285.4	84.6	2384.6	88.3	2484.	92.	2583.3	95.7	2682.7	99.4	2782.1	103.	2881.4	106.7	2980.8	110.4	3080.2	114.2
42	976.7	36.1	2148.9	79.6	2246.7	83.2	2344.2	86.8	2441.9	90.4	2539.6	94.1	2637.2	97.7	2734.9	101.3	2832.6	104.9	2930.3	108.4	3028.	112.3
43	959.9	35.5	2111.8	78.2	2207.9	81.8	2303.8	85.3	2399.8	88.9	2495.8	92.4	2591.8	96.	2687.8	99.5	2783.8	103.1	2879.6	106.7	2975.7	110.3
44	943.1	34.9	2074.8	76.8	2169.2	80.3	2263.4	83.8	2357.7	87.3	2452.	90.8	2546.3	94.3	2640.6	97.8	2734.9	101.3	2829.3	104.8	2923.5	108.4
45	926.2	34.3	2037.7	75.5	2130.4	78.9	2223.	82.3	2315.6	85.8	2408.2	89.2	2500.8	92.6	2593.5	96.	2686.1	99.5	2778.7	102.9	2871.3	106.5
46	909.4	33.6	2000.7	74.1	2091.7	77.5	2182.6	80.8	2273.5	84.2	2364.4	87.6	2455.4	90.9	2546.3	94.3	2637.2	97.7	2728.2	101.1	2819.1	104.5
47	892.6	33.	1963.6	72.7	2053.	76.0	2142.1	79.3	2231.4	82.6	2320.6	86.	2409.9	89.2	2499.2	92.6	2588.4	95.9	2677.7	99.2	2766.9	102.6
48	875.7	32.4	1926.6	71.4	2014.1	74.6	2101.7	77.8	2189.3	81.1	2276.9	84.3	2364.4	87.6	2452.	90.8	2539.6	94.1	2627.1	97.3	2714.7	100.6
49	858.9	31.8	1889.5	70.	1975.4	73.2	2161.3	76.3	2147.2	79.5	2233.	82.7	2319.	85.9	2404.8	89.1	2490.7	92.3	2576.6	95.4	2662.5	98.7
50	842.	31.1	1852.5	68.6	1936.7	71.7	2020.9	74.8	2105.1	78.	2189.3	81.1	2273.5	84.2	2357.7	87.3	2441.9	90.4	2526.1	93.6	2610.3	96.8
51	825.2	30.5	1815.4	67.2	1897.9	70.3	1980.5	73.4	2063.	76.4	2145.5	79.4	2228.	82.5	2310.5	85.6	2393.1	88.6	2475.6	91.7	2558.1	94.8
52	808.4	29.9	1778.4	65.9	1859.2	68.9	1940.	71.9	2020.9	74.8	2101.7	77.8	2182.5	80.8	2263.4	83.8	2344.2	86.8	2425.	89.8	2505.9	92.9
53	791.5	29.3	1741.3	64.5	1820.5	67.4	1899.6	70.4	1978.8	73.3	2057.9	76.2	2137.1	79.2	2216.2	82.1	2295.4	85.0	2374.5	87.9	2453.7	90.9
54	774.7	28.6	1704.3	63.1	1781.7	66.	1859.2	68.9	1936.7	71.7	2014.1	74.6	2091.6	77.5	2169.1	80.3	2246.5	83.2	2324.	86.1	2401.5	88.9
55	757.83	28.1	1667.2	61.7	1743.	64.6	1818.8	67.4	1894.6	70.2	1970.4	73.0	2046.1	75.8	2121.9	78.6	2197.7	81.4	2273.5	84.2	2349.3	87.
	Water.		S'dstones from 2.1-2.73										P.Trap 2.75		Poor T. R.		Fair T. R.		Good T. R.		Best T. R.	
							Limestone, from 2.4 to 2.86, aver. for roads 2.7								P. Hudson R. or Conn.				Best H.R. or Orange M.			

Abbreviations: P. poor; T. R. trap rock; R. river; M. mountain; S'dstones, sandstones.

$S = 2$ (. . . . . . length of pipe line in feet.
$D^{1.25}$ × 5280 feet.

By the use of logarithms (Table No. 47) having
certain quantities the formula can be solved fo
others.

For the formula, the author is indebted to "No
Hydraulics" by D. M. Greene, C. E., late Direc
the Rensselaer Polytechnic Institute of Troy,
as in use prior to his graduation in 1889.

After making personally or by assistants, s
hundred experiments under varying conditions
time to time, as opportunity was offered for reas
cost, during and after the construction of water
in various sections of the country, the author foun
in 116 different instances that the actual agree
the discharge as calculated by (a) within from o
per cent. while many other popular formulae g
sults in error by as much as 34 per cent. To pr
check, cross check and verify the tables has in
over 100,000 separate calculations.

Should any evident error, typographical or in
tables, be noticed, it would be much appreciate
author's attention is called to it, that it may be c
ed in subsequent editions of this work.

!ata.

›wing the tables will be found other tables and ıat will facilitate their rapid and accurate use.

nple No. 1, Given, a new 12" cast iron pipe line, long, required the discharge per day when pres-ıuge shows a loss of head of 10 lbs. 10÷5=2lbs, ile. In 6th column of Table No. 127 we find bs. or near enough to two lbs. for all practical es. Opposite in 10th column we find 812,184 ; per day, the discharge required. If the line is e Tables Nos. 135 and 136.

nple No. 2.—Given fall of 200', required size of ‡ miles long that will deliver 3,000,000 gallons of ɔer day under working pressure of 68 lbs. By 141, 68lbs=157' head. Total head (200—157')÷4= ɩs the head we can loose per mile. Taking next in the tables, to provide for contingencies, we ɔr 16" and head lost of 10'.46 per mile, discharge 7 millions per day, or for discharge of 3.068 mil ıead lost of 13.1×4=52'.4 in 4 miles, and instead ɔs. working pressure we would have 200'—52'.4= ›r 64 lbs. pressure nearly. If this loss of 4 lbs. .) is not permissible, and 2.707 millions is too ı discharge, then we must lay an 18" and we find ɔle No. 125 that for a loss of head of 10'.71 per ˙ 42'.84 in 4 miles an 18" would deliver when new illions* or allowing for tuberculation, etc. 0.79 .s capacity, the 18" would deliver 3,000,000 per : some years after construction, under 64 lbs. work ›ssure, while when new, (see between 2'.6 and 2'.7 y Table No. 125) it would deliver 3,000,000 under 74.5 lbs working pressure.

last column of the Tables give discharge in Coli-miners inches. See Tables Nos. 160 and 161.

ny case when any one of the eleven quantities in the tables does not correspond with the figures enting the case at hand, use simple proportion. ing the next lower figures, however, a slight factor is introduced and rapid work facilitated.

›n discharge is through several sizes of pipe lines ɔession as main line and part of distribution sys-se Table No. 140.

*'nder 68 lbs. pressure.

Table No. 120.

DIAMETER 48 INCHES.

Table showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Head Lost or Grade Required to Produce Velocity. In Feet per Mile.	One Foot In	Pressure Lost in Pounds per Sq. in. in 1000 feet.	Pressure Lost in Pounds per Sq. in. in Mile	Discharge in Cubic Feet per Second.	Discharge in United States Gall's Per Minute.	Discharge in United States Gall's Per Hour.	Discharge in United States Gall's Per Day Millions.	Miners Inches 4-inch Head.
.1	0.00011	.0058	172. *	.0005	.0025	1.26	564.	In thousands 33.8	.8	62.8
.2	0.00038	.0202	49.4*	.0017	.0087	2.51	1128.	67.7	1.6	125.7
.3	0.00079	.0419	23.8*	.0034	.0182	3.77	1692.	101.5	2.4	188.5
.4	0.00133	.0704	75188.	.0057	.0305	5.03	2256.	135.4	3.2	251.1
.5	0.00199	.1052	50251.	.0086	.0455	6.28	2820.	169.2	4.1	314.2
.6	0.00276	.1461	36231.	.012	.0633	7.54	3384.	203.	4.9	377.
.7	0.00365	.1918	27397.	.0158	.0831	8.8	3948	236.9	5.7	439.8
.8	0.00464	.2452	21551.	.0201	.1072	10.05	4512.	270.7	6.5	502.8
.9	0.00574	.3031	17421.	.0249	.1313	11.31	5076.	304.6	7.3	565.5
1.0	0.00694	0.36	14409.	0.03	0.16	12.57	5640.	338388.	8.12	628.3
1.1	0.00824	0.44	12137.	0.036	0.19	13.82	6204.	372226.	8.93	691.16
1.2	0.0096	0.51	10378.	0.042	0.22	15.08	6768.	406066.	9.75	754.
1.3	0.0111	0.59	8985.	0.048	0.25	16.34	7332.	439904.	10.56	816.83
1.4	0.01271	0.67	7868.	0.055	0.29	17.59	7896.	473743.	11.37	879.67
1.5	0.0144	0.76	6944.	0.062	0.33	18.85	8460.	507582.	12.18	942.5
1.6	0.01617	0.85	6163.	0.07	0.37	20.11	9024.	541421.	12.99	1005.33
1.7	0.01803	0.95	5544.	0.078	0.41	21.36	9588.	575260.	13.81	1068.16
1.8	0.01999	1.06	5002.	0.087	0.46	22.62	10152.	609098	14.62	1131.
1.9	0.02203	1.16	4538.	0.096	0.50	23.88	10716.	642937.	15.43	1194.83
2.0	0.0242	1.28	4132.	0.105	0.55	25.13	11280.	676776.	16.24	1257.66
2.1	0.0264	1.4	3784.	0.114	0.6	26.39	11844.	710615.	17.05	1319.
2.2	0.0287	1.52	3480.	0.124	0.66	27.65	12408.	744454.	17.87	1382.
2.3	0.0311	1.64	3212.	0.135	0.71	28.9	12972.	778292	18.68	1445.
2.4	0.0336	1.78	2975.	0.146	0.77	30.16	13536.	812131.	19.49	1508.
2.5	0.0361	1.91	2769.	0.157	0.83	31.42	14100.	845970.	20.3	1571.
2.6	0.0388	2.05	2580.	0.168	0.89	32.67	14663.	879809.	21.12	1634.
2.7	0.0415	2.19	2411.	0.18	0.95	33.93	15227.	913648.	21.93	1697.
2.8	0.0443	2.34	2258.	0.192	1.01	35.19	15791.	947486.	22.74	1759.
2.9	0.0472	2.49	2120.	0.204	1.08	36.44	16355.	981325.	23.55	1822.
3.0	0.0514	2.65	1994.	0.217	1.15	37.7	16919.	1015164.	24.36	1885.
3.1	0.0532	2.81	1880.	0.23	1.22	38.96	17483.	1049003.	25.18	1948.
3.2	0.0563	2.97	1776.	0.244	1.29	40.21	18047.	1082842.	25.99	2011.
3.3	0.0595	3.14	1680.	0.258	1.36	41.47	18611.	1116680.	26.8	2073.
3.4	0.0628	3.32	1592.	0.272	1.44	42.73	19175.	1150519.	27.61	2136.
3.5	0.0662	3.49	1511.	0 287	1.51	43.98	19739.	1184358.	28.42	2199.
3.6	0.0696	3.68	1436.	0.302	1.59	45.24	20303.	1218197	29.24	2262.
3.7	0.0731	3.86	1367.	0.317	1.67	46.5	20867.	1252036	30 05	2325.
3.8	0.0767	4.05	1303.	0.332	1.76	47.75	21431.	1285874.	30.86	2388.
3.9	0.0804	4.25	1244.	0.348	1.84	49.01	21995.	1319713.	31.67	2450.
4.0	0.08415	4.44	1188.	0.365	1.93	50.27	22559.	1353552.	32.48	2513.
4.1	0.0879	4.65	1136.	0.381	2.01	51.52	23123.	1387391.	33.3	2576.
4.2	0.0919	4.85	1088.	0.398	2.1	52.78	23687.	1421230.	34.11	2639.
4.3	0.0959	5.06	1043.	0.415	2.18	54.04	24251.	1455068.	34.92	2702.
4.4	0.0999	5.28	1001.	0.433	2.29	55.29	24815.	1488907	35.73	2765.
4.5	0.104	5.49	961.3	0.451	2.38	56.55	25379.	1522746.	36.55	2827.
4.6	0.1082	5.71	923.9	0.469	2.48	57.81	25943.	1556585	37.36	2890.
4.7	0.1125	5.94	888.9	0.487	2.57	59.06	26507.	1590424	38.17	2953.
4.8	0.1168	6.17	855.8	0.506	2.67	60.32	27071.	1624262.	38.98	3016.
4.9	0.1212	6.4	824.6	0.525	2.77	61.57	27635.	1658101.	39.79	3079.
5.0	0.1257	6.64	795.2	0.545	2.88	62.83	28199.	1691940.	40.61	3142.
5.5	0.1493	7.88	669.8	0.647	3.42	69.11	31019.	1861134.	44.67	3456.
6.0	0.1746	9.22	572.7	0.756	3.99	75.4	33839.	2030328.	48.73	3770.
6.5	0.2016	10.64	495.9	0.874	4.61	81.68	36659.	2199522.	52.79	4084.
7.0	0.2304	12.16	433.9	0.998	5.27	87.96	39479.	2368716.	56.85	4398.
7.5	0.2609	13.77	383.3	1.13	5.97	94.25	42229.	2537910	60.91	4712.
8.0	0.293	15.34	341.2	1.27	6.7	100.53	45118.	2707104	64.97	5027.
8.5	0.3268	17.26	305.9	1.42	7.48	106.81	47938.	2876298.	69.03	5341.
9.0	0.3623	19.12	276.	1.57	8.29	113.1	50758.	3045492.	73.09	5655.
9.5	0.3992	21.08	250.4	1.73	9.13	119.38	53578.	3214686.	77.15	5969.

* *Miles.*

Table No. 120. (Continued.)

DIAMETER 48 INCHES.

Table showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	In Feet per Mile.	One Foot In	Pressure Lost in Pounds per Sq. In. in 1000 feet.	Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day Millions	Miners Inches 4-inch Head.
10.0	**0.4379**	**23.12**	**228.3**	**1.9**	**10.01**	**125.66**	**56398.**	**3383880.**	**81.21**	**6283.**
10.5	0.4781	25.24	209.1	2.07	10.93	131.95	59218.	3553074.	85.27	6597.
11.0	0.5198	27.45	192.3	2.25	11.89	138.23	62038.	3722268.	89.33	6912.
11.5	0.563	29.73	177.5	2.44	12.88	144.51	64858.	3891462.	93.39	7226.
12.0	0.608	32.10	164.5	2.63	13.9	150.8	67678.	4060656.	97.45	7540.
12.5	**0.6544**	**34.55**	**152.8**	**2.83**	**14.96**	**158.07**	**70498.**	**4229850.**	**101.52**	**7854.**
13.0	0.7022	37.08	142.4	3.04	16.06	163.36	73317.	4399040.	105.58	8168.
13.5	0.7516	39.68	133.	3.26	17.19	169.65	76137.	4568238.	109.64	8482.
14.0	0.8023	42.36	124.6	3.48	18.35	175.92	78957.	4737432.	113.7	8797.
14.5	0.847	45.13	117.	3.7	19.55	182.21	81777.	4906626.	117.76	9111.
15.0	**0.9085**	**47.97**	**110.**	**3.94**	**20.78**	**188.5**	**84597.**	**5075820.**	**121.82**	**9425.**

COST TO CONSTRUCT 48" CAST IRON WATER PIPE LINES.

	Cost per foot.	Cost per mile.
LEAD—Depth, average 2⅝"; amt. per joint 90 to 112 lbs.; average 96 lbs.; average per foot 8 lbs. COST, @ 5c. per lb. in the work..	$0.40	$2112
HEMP—Amt. per joint, average 4.5 lbs.; per foot 0.375 lbs. COST, @ 7c. per lb. in the work	0.026	137
EXCAVATION—6' wide x 8' deep (4' cover nearly). 2 cu. yds. per foot, much double handling is required. COST, including BELL-HOLES @ 40c. cu. yd..........	0.80	4224
REFILLING and TAMPING—½ COST to excavate	0.40	2112
CARTAGE—Average haul, 2 miles, one pipe on truck	0.125	660
PIPE LAYING—Under average difficulties, COST $3.00 per length or..........	0.25	1320
FOREMAN, timekeepers, watchman, insurance, repairs, incidentals..........	0.48	2534
AVERAGE COST in CITY STREETS, exclusive of pipe and re-paving..........	$2.48	$13099
AVERAGE COST in Borough of Brooklyn, N. Y., in 1896..........	$2.43	$12830

FOR COST of PIPE, per pound, at any price per ton or gross ton, see Table No. 133.

FOR COST for FREIGHT or CARTAGE, see Table No. 133.

FOR COST to RESTORE PAVEMENTS, see Table No. 132.

FLANGED PIPE—Standard dimensions. See Table No. 134.

AREA 48" pipe, 12.56 sq. ft. Contents per foot in length, 94.02 U. S. gallons.

Table No. [illegible]

DIAMETER [illegible] INCHES.

Table Showing [illegible] and discharging capacity for different [illegible] Pipe Lines.

[illegible]	[illegible]		[illegible]	[illegible]		Discharge in				
	[illegible]					[illegible]	[illegible]			Miners Inches [illegible] Head.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Per Minute	Per Hour	Per Minute	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table No. 121. (Continued.)

DIAMETER 36 INCHES.

Table Showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Velocity ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Sq. in. in 1000 feet	Mile	Discharge in Cub. Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day	Miners Inches 4-inch Head.
5	0.685	36.17	146.	2.959	15.67	74.22	33310.	1998599.	47.96	3710.7
0	0.7449	39.33	134.3	3.23	17.04	77.75	34890.	2093770.	50.25	3887.4
5	0.8069	42.6	124.	3.5	18.46	81.29	36482.	2188941.	52.53	4064.1
0	0.8711	46.0	114.8	3.77	19.93	84.82	38068.	2284113.	54.82	4240.8
5	**0.9375**	**49.5**	**106.7**	**4.06**	**21.44**	**88.36**	**39654.**	**2379284.**	**57.1**	**4417.5**
0	1.0062	53.12	99.4	4.36	23.01	91.89	41240.	2474455.	59.38	4594.2
5	1.0769	56.86	92.9	4.67	24.66	95.43	42827.	2569627.	61.67	4770.9
0	1.15	60.69	87.	4.98	26.29	98.96	44413.	2664798.	63.95	4947.6
5	1.225	64.66	81.7	5.31	28.01	102.49	45999.	2759969.	66.24	5124.3
0	**1.302**	**68.73**	**76.8**	**5.64**	**29.77**	**106.03**	**47586.**	**2855141.**	**68.52**	**5301.5**

COST TO CONSTRUCT 36" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile.
LEAD—Depth, average, 2½"; amt. per joint, 68 to 80 lbs., average 70 lbs.; per foot, 5.83 lbs. COST, @ 5c. per lb. in the work	$0.291	$1536.48
HEMP—Amt. per joint, average 3 lbs.; per foot, 0.25 lbs. COST, @ 7c. per lb. in the work	0.0175	92.40
EXCAVATION—5' wide x 7' deep (4' cover nearly). 1.5 cu. yds. per foot. Much double hauling is required. COST, including BELL-HOLES, @ 40c	0.60	3168.00
RE-FILLING and TAMPING—½ COST to excavate	0.30	1584.00
CARTAGE—Average haul, 2 miles, one pipe on truck	0.11	581.80
PIPE LAYING, under average difficulties, with proper tools, etc	0.22	1161.60
FOREMAN, timekeepers, watchman, insurance, repairs, incidentals	0.36	1900.80
AVERAGE COST in CITY STREETS, exclusive of pipe and repaving	$1.90	$10024.08
AVERAGE COST in Borough of Brooklyn, N. Y., in 1896	$2.00	$10560.

For COST of PIPE per pound at any price per net or gross ton see Table No. 133.

For COST for FREIGHT and CARTAGE see Table No. 13.

For COST to RESTORE pavements, see Table No. 132.

FLANGED PIPE, standard dimensions, see Table No. 4.

AREA—36 inch pipe, 7.07 sq. ft. contents per foot in length, 52.88 U. S. Gallons.

Table No. 122.

DIAMETER 30 INCHES.

Table showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	In Feet per Mile.	One Foot in	Pressure Lost in Pounds per Square in. in 100 feet.	in Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day Millions.	Miners Inches 4-inch Head.
.1	.0002	.0105	505190.	.0009	.0045	.49	220.	13218.	.32	24.6
.2	.00069	.0364	145042.	.003	.0158	.98	441.	26436.	.63	49.0
.3	.00143	.0755	69907.	.0062	.0327	1.47	661.	39655.	.95	73.6
.4	.0024	.1267	41594.	.0104	.0549	1.96	881.	52873.	1.27	98.2
.5	.00356	.1894	27878	.0155	.082	2.46	1102.	66091	1.59	122.7
.6	.00498	.263	20080.	.0216	.114	2.95	1322.	79309.	1.90	147.3
.7	.00657	.347	15216.	.0285	.1504	3.44	1542.	92527.	2.22	171.7
.8	.00836	.4423	11964.	.0362	.191	3.93	1762.	105746.	2.54	196.3
.9	.01033	.5456	9681.	.0447	.236	4.42	1983.	118964.	2.85	220.9
1.0	0.01248	0.659	8007.	0.054	0.29	4.91	2203.	132182.	3.17	245.4
1.1	0.01482	0.782	6750.	0.064	0.34	5.4	2423.	145401.	3.49	270
1.2	0.01734	0.915	5767.	0.075	0.4	5.89	2644.	158619.	3.81	294.5
1.3	0.02003	1.058	4993.	0.086	0.46	6.38	2864.	171837.	4.12	319.1
1.4	0.02289	1.209	4370.	0.099	0.52	6.87	3084.	185056.	4.44	343.6
1.5	0.02591	1.368	3859.	0.112	0.59	7.37	3305.	198274.	4.76	368.1
1.6	0.02911	1.537	3436.	0.126	0.67	7.85	3525.	211492.	5.08	392.7
1.7	0.03246	1.714	3081.	0.141	0.74	8.35	3745.	224710.	5.39	417.2
1.8	0.03598	1.9	2780.	0.156	0.82	8.84	3965.	237929.	5.71	441.8
1.9	0.03965	2.09	2522.	0.172	0.91	9.33	4186.	251147.	6.03	466.3
2.0	0.04355	2.3	2296.	0.188	1.0	9.82	4406.	264365.	6.34	490.9
2.1	0.04755	2.51	2103.	0.206	1.09	10.31	4626.	277583.	6.66	515.4
2.2	0.05171	2.73	1934.	0.224	1.18	10.8	4847	290802.	6.98	540
2.3	0.05602	2.96	1785.	0.243	1.28	11.29	5067.	304020.	7.3	564.5
2.4	0.06049	3.19	1653.	0.262	1.38	11.78	5287.	317238.	7.61	589
2.5	0.06499	3.43	1539.	0.282	1.49	12.27	5508.	330456.	7.93	613.6
2.6	0.06974	3.68	1434.	0.302	1.6	12.76	5728.	343675.	8.25	638.[illegible]
2.7	0.07464	3.94	1340.	0.324	1.71	13.25	5948.	356893.	8.57	662.7
2.8	0.07969	4.21	1255.	0.345	1.82	13.74	6169.	370111.	8.82	687.2
2.9	0.08489	4.48	1178.	0.368	1.94	14.24	6389.	383329.	9.2	711.7
3.0	0.09022	4.76	1103.	0.391	2.07	14.73	6609.	396548.	9.52	736.3
3.1	0.09571	5.05	1045.	0.415	2.2	15.22	6829.	409766.	9.83	760.8
3.2	0.1013	5.35	986.7	0.439	2.32	15.71	7050.	422985.	10.15	785.3
3.3	0.1071	5.66	933.5	0.464	2.45	16.2	7270.	436202.	10.47	809.9
3.4	0.1130	5.97	884.7	0.49	2.59	16.69	7490.	449421.	10.79	834.[illegible]
3.5	0.1191	6.29	839.8	0.516	2.73	17.18	7711.	462639.	11.1	859.0
3.6	0.1253	6.62	798.2	0.543	2.87	17.67	7931.	475857.	11.42	883.5
3.7	0.1316	6.95	759.9	0.571	3.01	18.16	8151.	489075.	11.74	908.1
3.8	0.1381	7.29	724.2	0.599	3.16	18.65	8372.	502294.	12.06	932.6
3.9	0.1447	7.64	691.1	0.627	3.31	19.14	8592.	515512.	12.37	957.1
4.0	0.1516	8.0	660.3	0.656	3.47	19.63	8812.	528730.	12.69	981.7
4.1	0.1584	8.36	631.6	0.686	3.62	20.13	9032.	541948.	13.01	1006.[illegible]
4.2	0.1654	8.73	604.8	0.717	3.78	20.62	9253.	555167.	13.32	1030.8
4.3	0.1725	9.11	579.7	0.748	3.95	21.11	9473.	568385.	13.64	1055.3
4.4	0.1798	9.49	556.2	0.779	4.12	21.6	9693.	581603.	13.96	1079.9
4.5	0.1872	9.88	534.2	0.812	4.29	22.09	9914.	594821.	14.28	1104.4
4.6	0.1948	10.28	513.5	0.844	4.46	22.58	10134.	608040.	14.59	1129.0
4.7	0.2025	10.69	494.	0.878	4.63	23.07	10354.	621258.	14.91	1153.5
4.8	0.2103	11.1	475.6	0.911	4.81	23.56	10575.	634476.	15.23	1178.0
4.9	0.2182	11.52	458.3	0.946	4.99	24.05	10795.	647694.	15.54	1202.6
5.0	0.2263	11.95	441.9	0.981	5.18	24.54	11015.	660913.	15.86	1227.1
5.5	0.2687	14.19	372.2	1.165	6.15	27.0	12117.	727004.	17.45	1349.[illegible]
6.0	0.3142	16.59	318.3	1.362	7.19	29.45	13218.	793095.	19.03	1472.[illegible]
6.5	0.3629	19.16	275.6	1.573	8.31	31.91	14320.	859187.	20.62	1595.[illegible]
7.0	0.4147	21.89	241.2	1.798	9.49	34.36	15422.	925278.	22.21	1718.[illegible]
7.5	0.4695	24.79	213.	2.035	10.75	36.82	16523.	991369.	23.79	1840.[illegible]
8.0	0.5273	27.84	189.6	2.286	12.07	39.27	17624.	1057460.	25.38	1963.[illegible]
8.5	0.5881	31.06	170.	2.55	13.46	41.72	18726.	1123552.	26.96	[illegible]
9.0	0.6519	34.42	153.4	2.83	14.92	44.18	19827.	1189643.	28.55	[illegible]
9.5	0.7187	37.94	139.2	3.115	16.45	46.63	20929.	1255734.	30.14	[illegible]
10.0	0.788	41.6	126.9	3.416	18.04	49.09	22030.	1321826.	31.72	[illegible]

Table No. 122. (Continued.)

DIAMETER 30 INCHES.

owing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

ad Lost or Grade Required to oduce Velocity.			Pressure Lost in Pounds per Square in. in		Discharge in				
In Feet per		One Foot			Cubic Feet per Second.	United States Gall's			Miners Inches 4-inch Head.
Ft.	Mile.	In	1000 feet.	Mile		Per Minute.	Per Hour.	Per Day Millions.	
8	45.43	116.2	3.729	19.69	51.54	23132.	1387917.	33.31	2577.08
5	49.39	106.9	4.065	21.41	54.0	24233.	1454008.	34.9	2699.8
	53.51	98.7	4.393	23.19	56.45	25335.	1520099.	36.48	2822.52
	57.77	91.6	4.743	25.04	58.9	26437.	1586191.	38.07	2945.24
	62.17	83.4	5.104	26.95	61.34	27538.	1652282.	39.65	3067.96
	66.72	79.1	5.478	28.92	63.81	28640.	1718373.	41.24	3190.68
	71.41	73.9	5.863	30.95	66.27	29741.	1784464.	42.83	3313.39
	76.32	69.3	6.258	33.04	68.72	30843.	1850556.	44.41	3436.11
	81.21	65.0	6.667	35.2	71.18	31944.	1916647.	46.0	3558.83
	86.32	61.2	7.087	37.42	73.63	33046.	1982738.	47.59	3681.55

O CONSTRUCT 30" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile.
Depth, average, 2⅜"; Amt. per 45 to 60 lbs.; average 48 lbs.; per lbs. COST, @ 5c. per lb. in the	$0.20	$1056.00
Amt. per joint, average, 2 lbs. Per 166 lbs. COST, @ 7c. per lb. in the	0.012	63.36
ATION—4.'5 wide x 6.'5 deep (4' nearly), 31 cu. ft.* per foot. Much handling is required. COST, in- g "bell-holes" @ 1.5c..................	0.465	2455.20
LING and TAMPING, 40% of COST avate	0.186	982.08
GE, average haul 2 miles, one pipe ck..	0.10	528.00
AYING, under average difficulties, roper tools, etc........................	0.20	1056.00
AN, timekeeper, watchman, insur- repairs, incidentals.....................	0.30	1584.00
RAGE COST in CITY STREETS, cclusive of pipe and repaving......	$1.463	$7724.64

COST of PIPE per pound at any price per ton ton, see Table No. 133.

COST for FREIGHT or CARTAGE, see Table

COST to RESTORE PAVEMENTS, see Table No.

GED PIPE—Standard dimensions. See Table No.

30" pipe, 4.59 sq. ft. Contents per foot in length, S. gallons.
es "bell-holes."

Table No. 123.

DIAMETER 24 INCHES.

Table showing loss of head in pressure and discharging of different according to Cast Iron Pipe Lines.

[illegible]	Loss of Head ... Pressure Velocity: In Feet per 1000 ft.	Loss of Head ... Pressure Velocity: per Mile	Per Cent	Pressure ... per sq. in.: per 1000 ft.	Pressure ... per sq. in.: Per Mile	Velocity in Feet per Second	Discharge in United States Gall's: Per Minute	Discharge in United States Gall's: Per Hour	Discharge in United States Gall's: Per Day Millions
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table No. 123. (Continued.)

DIAMETER 24 INCHES.

ing loss of head and pressure and discharging capacity r different velocities for Cast Iron Pipe Lines.

Lost or Grade Required to uce Velocity. Feet per			Pressure Lost in Pounds per Sq. In. in		Discharge in				
					Cub. Feet per Second.	United States Gall's			Miners Inches 4-inch Head.
t.	Mile.	One Foot In	1000 feet	Mile		Per Minute.	Per Hour.	Per Day Millions.	
	60.04	87.9	4.929	26.03	32.99	14804.	888276.	21.32	1649.36
	65.29	80.9	5.36	28.3	34.56	15509.	930575.	22.33	1720.92
	70.72	74.7	5.800	30.66	36.13	16214.	972874.	23.35	1800.48
	76.35	69.2	6.268	33.1	37.7	16919.	1015173.	24.36	1885.04
	82.17	64.3	6.746	35.62	39.27	17624.	1057472.	25.38	1963.6
	88.18	59.9	7.24	38.23	40.84	18329.	1099770.	26.39	2042.16
	94.38	55.9	7.749	40.91	42.41	19034.	1142069.	27.41	2120.72
	100.7	52.4	8.271	43.67	43.98	19739.	1184368.	28.42	2199.28
	107.3	49.2	8.812	46.55	45.55	20444.	1226667.	29.44	2277.84
	114.1	46.3	9.367	49.46	47.12	21149.	1268967.	30.46	2356.4

O CONSTRUCT 24" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile.
Depth, average 2¼". Amt. per joint lbs, average 36 lbs. Per foot, 3 lbs. @ 5c. per lb. in work	$0.15	$792.00
-Amt. per joint, average, 1.75 lbs. ot, 0.146 lbs. COST @ 7c. per lb. in ork	0.01	52.80
ATION—4' wide x 6' deep (4' cover), 1 cu. yd. per foot, less double ig than with for 30". COST, includell-holes"	0.35	1848.00
LING and TAMPING—½ COST to te	0.17 5	924.00
GE—Average haul, 2 miles, one pipe ck	0.09	475.20
AYING—Under average difficulties, roper tools, etc	0.18	950.40
AN, Timekeeper, Watchman, Ine, Repairs, incidentals	0.24	1267.29
AGE COST in CITY STREETS, sive of pipe and repaving	$1.195	$6309.60
AGE COST through FIELDS and OUNTRY ROADS	$1.08	5702.40

COST of PIPE per pound at any price per net or n see Table No. 133.

COST for FREIGHT or CARTAGE see Table No.

COST to RESTORE PAVEMENTS see Table No.

GED PIPE—Standard dimensions. See Table No.

4" pipe, 3.14 sq. ft. Contents per foot in length, 5. gallons.

Table No. 124.

DIAMETER 20 INCHES.

Table showing loss of head and pressure and discharging capac[illegible] different velocities for Cast Iron Pipe Lines.

Velocity in feet per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Head Lost or Grade Required to Produce Velocity. In Feet per Mile.	Head Lost or Grade Required to Produce Velocity. One Foot in	Pressure Lost in Pounds per Square In. in 1000 feet.	Pressure Lost in Pounds per Square In. in Mile	Discharge in Cub. Feet per Second.	Discharge in United States Gall's Per Minute.	Discharge in United States Gall's Per Hour.	Discharge in United States Gall's Per Day
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table No. 124. (Continued.)

DIAMETER 20 INCHES.

loss of head and pressure and discharging capacity
ifferent velocities for Cast Iron Pipe Lines.

or Grade red to Velocity.		Pressure Lost in Pounds per Sq. in. in		Discharge in				
				Cub. Feet	United States Gall's.			Miners Inches 4-inch Head.
ile.	One Foot In	1000 feet	Mile	per Second.	Per Minute.	Per Hour.	Per Day	
5.44	70.	6.194	32.7	22.91	10281.	616890.	14.81	1145.36
2.04	64.4	6.735	35.56	24.0	10770.	646266.	15.51	1199.9
8.87	59.4	7.296	38.52	25.00	11260.	675642.	16.22	1254.44
5.94	55.	7.876	41.59	26.18	11759.	705018.	16.92	1308.99
3.3	51.1	8.477	44.76	27.27	12239.	734393.	17.63	1363.53
0.8	47.6	9.097	48.03	28.36	12729.	763769.	18.33	1418.07
8.6	44.5	9.737	51.41	29.45	13218.	793149.	19.04	1472.61
6.6	41.7	10.390	54.86	30.54	13708.	822521.	19.74	1527.15
4.9	39.1	11.07	58.47	31.63	14198.	851896.	20.45	1581.69
3.4	36.8	11.77	62.15	32.72	14687.	881272.	21.15	1636.23

CONSTRUCT 20" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile.
pth, average 2¼". Amt. per joint lbs., average 32 lbs. Per foot. COST @ 5c. per lb. in the work..	$0.133	$702.24
nt. per joint, average 1.5 lbs. 0.125 lbs. COST at 7c. per lb. ork	0.00875	46.20
ION*, RE-FILLING and TAMP- luding "bell-holes"	0.42	2217.60
—Average haul, 2 miles, 2 pipes	0.05	264.00
ING—Under average difficulties, per tools, etc.........................	0.15	792.00
N, Timekeeper, Watchman, In- Repairs, Incidentals...............	0.20	1056.00
E COST in CITY STREETS, ve of pipe and repaving............	$0.96	$5078.04
E COST through FIELDS and NTRY ROADS	0.83	4382.40

T OF PIPE per pound at any price per net or see Table No. 133.

T for FREIGHT or CARTAGE see Table No.

D PIPE—Standard dimensions see Table No

0" pipe, 2.18 sq. ft. Contents per foot in length, gallons.

of excavation per foot, average, pipe covered

Table No. 125. (Continued.)

DIAMETER 13 INCHES.

Table showing loss of head and pressure and discharging capacity … different velocities for Cast Iron Pipe Lines.

Velocity in Feet per Second	Head Lost or Grade Required to Produce Velocity: In Feet per 100 Ft.	In Feet per Mile	One Foot in	Pressure Lost in Pounds per Square In.: 100 Feet	Mile	Discharge in Cubic Feet per Second	U. S. Gall's per Minute	Per Hour	Per Day in Millions

Table No. 125. (Continued.)

DIAMETER 18 INCHES.

wing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

d Lost or Grade Required to duce Velocity. In Feet per Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Square In. in 1000 feet.	Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day Millions.	Miners Inches 4-inch Head.
9	86.02	61.4	7.062	37.29	18.55	8328.	499685.	12.060	927.75
2	93.56	56.4	7.681	40.56	19.43	8725.	523480.	12.635	971.93
9	101.3	52.1	8.319	43.92	20.32	9121.	547274.	13.209	1016.11
2	109.4	48.3	8.981	47.42	21.2	9518.	571069.	13.783	1060.29
	117.2	**44.8**	**9.666**	**50.8**	**22.08**	**9914.**	**594863.**	**14.358**	**1104.46**
8	126.3	41.8	10.37	54.77	22.97	10311.	618658.	14.932	1148.64
1	135.2	39.	11.1	58.62	23.85	10708.	642452.	15.506	1192.82
4	144.3	36.6	11.85	62.57	24.73	11104.	666247.	16.08	1237.
9	153.8	34.3	12.63	66.66	25.62	11501.	690041.	16.655	1281.18
5	**163.5**	**32.3**	**13.42**	**70.86**	**26.505**	**11897.**	**713836.**	**17.229**	**1325.36**

O CONSTRUCT 18" CAST IRON WATER PIPE LINES.

	Cost per— foot	mile.
-Depth, average, 2¼". Amount per average 27 lbs. Per foot, 2.25 lbs. @ 5c. per lb. in the work	$0.1125	$594.00
-Amount per joint, average, 1.25 lbs. oot, 0.104 lbs. COST, @ 7c. per lb. work	0.0073	38.54
ATION, RE-FILLING, TAMPING . ft. of each per ft. (4' cover near- COST, including "bell holes"	0.37	1953.60
GE—Average haul 2 miles, 2 pipes uck	0.045	237.60
LAYING—Under average difficulties, proper tools	0.12	633.60
IAN, Timekeeper, Watchman, In- ce, Repairs, Incidentals	0.18	950.40
AGE COST IN CITY STREETS, sive of pipe and repairing	$0.8348	$4407.74
AGE COST IN FIELDS and on NTRY ROADS	$0.71	$3748.80

COST of PIPE per pound at any price per net or on, see Table No. 133.

COST for FREIGHT and CARTAGE, see Table

COST to RESTORE PAVEMENTS, see Table 2

NGED PIPE, standard dimensions, see Table No.

A 18" pipe equals 1.77 sq. ft. Contents per foot in 13.21 U. S. gallons.

Table No. 12b.

DIAMETER 16 INCHES.

Table Showing [illegible] head and pressure and discharging capacity for different [illegible] for Cast Iron Pipe Lines.

[illegible]	[illegible]		[illegible]	Pressure Lost in Pounds per Square in. [illegible]		Discharge in				
	[illegible]					Cubic Feet per Second.	United States Gall's.			Miners Inches 4-inch Head.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Per Minute.	Per Hour	Per Day Millions.	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.139	63	3760	0.090	6.98
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.279	125.	7520.	0.180	13.96
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.419	188.	11280.	0.271	20.94
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.558	251.	15040.	0.361	27.92
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.698	313.	18800.	0.451	34.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.837	376.	22559.	0.541	41.89
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.977	438.	26319.	0.632	48.87
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.116	501.	30079.	0.722	55.85
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.256	564.	33839.	0.812	62.83
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.396	627.	37599.	0.902	69.81
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.535	689.	41358.	0.992	76.79
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.675	752.	45118.	1.082	83.77
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.815	815.	48879.	1.173	90.75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.954	877.	52639.	1.263	97.73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.094	940	56399	1.353	104.71
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60158.	1.443	111.69
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63919.	1.534	118.67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67679.	1.624	125.65
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71439.	1.714	132.63
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.792	1253	75199.	1.804	139.62
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78958.	1.895	146.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82719.	1.985	153.58
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	86479.	2.075	160.56
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1504.	90239.	2.165	167.54
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.49	1567	93999.	2.255	174.52
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1629	97758.	2.346	181.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1692.	101518.	2.436	188.48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1754.	105278.	2.526	195.46
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	109038.	2.616	202.44
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.188	1880.	112798.	2.707	209.43
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	116558.	2.797	216.41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2005.	120318.	2.887	223.39
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	124078.	2.977	230.37
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	127838.	3.068	237.35
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	131598	3.158	244.33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	135358.	3.248	251.31
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	139118.	3.338	258.29
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.429	265.27
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2444	[illegible]	3.519	272.25
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.609	279.24
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.699	286.22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	157918.	3.790	293.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.880	300.18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.970	307.16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	169197.	4.060	314.14
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.151	321.12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.241	328.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.331	335.08
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.421	342.06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3133.	187997.	4.511	349.05
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.963	383.95
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.414	418.86
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.865	453.76
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.316	488.67
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4700	281995.	6.767	523.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.219	558.48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.670	593.38
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.121	628.29
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.572	663.18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.023	[illegible]

Table No. 126. (Continued.)

DIAMETER 16 INCHES.

ble Showing loss of head and Pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

elocity ft. per Second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Square in. in 1000 Feet.	Mile.	Discharge in Cubic feet per Second	United States Gal's Per Minute.	Per Hour	Per Day Millions	Miners Inches 4-inch Head.
.5	1.888	99.7	52.9	8.185	43.22	14.661	6580.	394794.	9.475	731.
.0	2.053	108.4	48.7	8.9	46.99	15.358	6893.	413594	9.926	767.91
.5	2.224	117.4	44.9	9.641	50.91	16.056	7207.	432398.	10.377	802.81
2.0	2.402	126.8	41.6	10.41	54.96	16.754	7520.	451193	10.828	837.72
2.5	**2.585**	**136.5**	**38.6**	**11.2**	**59.15**	**17 452**	**7833.**	**469993.**	**11.279**	**872.62**
.0	2.774	146.3	36.	12.02	63 48	18 15	8147.	488792.	11.731	907.53
3.5	2.969	156.7	33.6	12.87	67.94	18.848	8460.	507592.	12.182	942.43
.0	3.169	167.3	31.5	13.73	72.52	19.546	8773.	526392.	12.633	977.34
.5	3.376	178.2	29.6	14.63	77.26	20.244	9086.	545192.	13.084	1012.24
5.0	**3.588**	**189.5**	**27.8**	**15.55**	**82.12**	**20.943**	**9400.**	**563991.**	**13.535**	**1047.15**

COST TO CONSTRUCT 16" CAST IRON WATER PIPE LINES.

	—Cost per— foot.	mile.
LEAD—Depth, average, 2⅛". Amount per joint, average 24 lbs.	$0.10	$528.00
HEMP—Amount per joint, average, 1 lb. Per foot, 0.083 lbs. COST @ 7c. per lb. in the work	0.0058	30.62
EXCAVATION—Amount, 17 cu. ft. per foot, including "bell holes" (4' cover). COST, including RE-FILLING and TAMPING	0.34	1795.20
CARTAGE—Average haul, 2 miles, 3 pipes on truck	0.0313	165.26
PIPE LAYING—Under average difficulties, with proper tools	0.10	528.00
FOREMAN, Timekeeper, Watchman, Insurance, Repairs, incidentals	0.16	844.80
AVERAGE COST IN CITY STREETS, exclusive of pipe and re-paving	$0.7371	$3891.88
Or, approximately	0.74	3900.00
AVERAGE COST in FIELDS and on COUNTRY ROADS	0.63	3326.00

FOR COST FOR PIPE per pound at any price per net or gross ton, see Table No. 133.

FOR COST FOR FREIGHT or CARTAGE, see Table No. 133.

For COST to RESTORE PAVEMENTS, see Table No. 132.

FLANGED PIPE, standard dimensions, see Table No. 134.

Area 16" pipe, 1.396 sq. ft. Contents per foot in length, 10.44 *U. S. gallons.*

Table No. 127.

DIAMETER 12 INCHES.

Table showing loss of head and pressure and discharging capac different velocities for Cast Iron Pipe Lines.

Velocity in ft per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Square In. in 1000 feet.	Mile	Discharge in Cub. Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day
.1	.00062	.03286	160700.	.0027	.014	.078	35	2115.	50761.
.2	.00216	.1144	46150.	.0094	.049	.157	71.	4230.	101523.
.3	.00449	.2374	22240.	.0195	.103	.236	106.	6345.	152284.
.4	.00754	.3984	13250.	.0327	.173	.314	141.	8460.	203046.
.5	.01128	.5953	8869.	.0488	.258	.393	176.	10575.	253807.
.6	.01565	.8265	6388.	.0678	.358	.471	212.	12690.	304569.
.7	.02066	1.091	4840.	.0895	.473	.550	247.	14805.	355330.
.8	.02627	1.387	3806.	.1138	.601	.628	282.	16920.	406092.
.9	.03248	1.715	3079.	.1407	.743	.707	317.	19035.	456853.
1.0	0.0392	2.07	2547.	0.17	0.898	0.785	352.	21150.	507615.
1.1	0.0466	2.46	2146.	0.202	1.067	0.863	388.	23265.	558376.
1.2	0.0545	2.89	1835.	0.236	1.248	0.942	423.	25380.	609138.
1.3	0.0629	3.32	1588.	0.273	1.441	1.021	458.	27495.	659899.
1.4	0.0719	3.98	1390.	0.312	1.724	1.099	493.	29610.	710661.
1.5	0.0814	4.3	1228.	0.353	1.864	1.178	528.	31725.	761423.
1.6	0.0915	4.83	1092.	0.397	2.095	1.256	564.	33840.	812184.
1.7	0.1021	5.39	980.	0.442	2.336	1.335	599.	35956.	862946.
1.8	0.1131	5.97	884.4	0.49	2.588	1.413	634.	38071.	913707.
1.9	0.1247	6.58	802.2	0.54	2.853	1.492	669.	40186.	964469.
2.0	0.1369	7.23	730.5	0.593	3.133	1.571	705.	42301.	1015230.
2.1	0.1495	7.89	669.	0.648	3.421	1.649	740.	44416.	1065992.
2.2	0.1626	8.58	629.5	0.705	3.72	1.727	775.	46531.	1116753.
2.3	0.1761	9.3	567.8	0.763	4.031	1.806	810.	48646.	1167515.
2.4	0.1902	10.04	525.9	0.824	4.352	1.884	846.	50761.	1218276.
2.5	0.2043	10.79	489.5	0 886	4.676	1.963	881.	52876.	1269038.
2.6	0.2192	11.58	456.1	0.95	5.018	2.042	916.	54991.	1319799.
2.7	0.2347	12.39	418.4	1.017	5.37	2.12	951.	57106.	1370561.
2.8	0.2505	13.23	399.2	1.086	5.734	2.199	987.	59221.	1421322.
2.9	0.2659	14.04	383.5	1.157	6.107	2.277	1022.	61336.	1472084.
3.0	0.2836	14.98	352.6	1.229	6.492	2.356	1057.	63451.	1522845.
3.1	0.3009	15.89	332.4	1.304	6.886	2.434	1092.	65566.	1573607.
3.2	0.3186	16.82	313.9	1.382	7.292	2.513	1128.	67682.	1624369.
3.3	0.3367	17.78	297.	1.46	7.707	2.591	1163.	69797.	1675130.
3.4	0.3553	18.76	281.4	1.54	8.132	2.67	1198.	71912.	1725892.
3.5	0.3744	19.77	267.1	1.623	8.568	2.748	1233.	74027.	1776653.
3.6	0.3938	20.79	253.9	1.707	9.013	2.827	1269.	76142.	1827415.
3.7	0.4138	21.84	241.7	1.793	9.469	2.905	1304.	78257.	1878176.
3.8	0.4341	22.92	230.4	1.882	9.933	2.984	1339.	80372.	1928938.
3.9	0.4548	24.02	219.9	1.972	10.41	3.063	1374.	82487.	1979699.
4.0	0.4761	25.13	210.1	2.064	10.9	3.141	1410.	84602.	2030461.
4.1	0.4977	26.28	200.9	2.157	11.39	3.22	1445.	86717.	2081222.
4.2	0.5197	27.44	192.4	2.253	11.9	3.298	1480.	88832.	2131984.
4.3	0.5422	28.63	184.4	2.35	12.41	3.377	1515.	90947.	2182745.
4.4	0.5651	29.84	176.9	2.507	12.93	3.455	1551.	93062.	2233507.
4.5	0.5865	31.07	169.9	2.551	13.47	3.534	1586.	95177.	2284269.
4.6	0.6123	32.33	163.3	2.654	14.01	3.612	1621.	97292.	2335030.
4.7	0.6364	33.6	157.1	2.759	14.57	3.691	1656.	99407.	2385792.
4.8	0.6609	34.9	151.3	2.865	15.13	3.769	1692.	101523.	2436553.
4.9	0.686	36.22	145.8	2.973	15.7	3.848	1727.	103638.	2487315.
5.0	0.7114	37.56	140.6	3.034	16.28	3.927	1762.	105575.	2538076.
5.5	0.8445	44.59	118.4	3.66	19.33	4.319	1938.	116328.	2791884.
6.0	0.9877	52.15	101.3	4.281	22.61	4.712	2115.	126903.	3045692.
6.5	1.141	60.25	87.6	4.945	26.11	5.105	2291.	137478.	3299490.
7.0	1.301	68.83	76.7	5.651	29.84	5.497	2467.	148054.	3553307.
7.5	1.476	77.93	67.7	6.393	33.78	5.89	2643.	158629.	3807114.
8.0	1.658	87.53	60.3	7.186	37.94	6.283	2820.	169205.	4060922.
8.5	1.849	97.6	54.1	8.012	42.28	6.675	2996.	179780.	4314730.
9.0	2.049	108.2	48.8	8.883	46.9	7.068	3172.	190355.	4568537.
9.5	2.259	119.3	44.2	9.791	51.69	7.461	3348.	200931.	4822345.
[illegible]	2.477	130.8	40.3	10.74	56.59	7.854	3525.	211506.	5076152

Table No. 127. (Continued.)

DIAMETER 12 INCHES.

able showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Ve- le- y ft. per Sec- ond.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	In Feet per Mile	One Foot In	Pressure Lost in Pounds per Square in. In 1000 feet.	Pressure Lost in Pounds per Square in. In Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	United States Gall's Per Hour.	United States Gall's Per Day	Miners Inches 4-inch Head.
0.5	2.705	142.8	36.9	11.72	61.9	8.240	3701.	222081.	5329961.	412.33
1.0	2.941	155.3	34.	12.75	67.31	8.639	3877.	232657.	5583768.	431.96
1.5	3.186	168.2	31.3	13.81	72.91	9.032	4053.	243232.	5837576.	451.6
2.0	3.439	181.6	29.	14.91	78.72	9.424	4230.	253807.	6091384.	471.23
2.5	3.702	195.5	27.	16.05	84.72	9.817	4406.	264382.	6345191.	490.87
3.0	3.972	209.8	25.1	17.22	90.92	10.21	4582.	274958.	6598999.	510.5
3.5	4.252	224.5	23.5	18.43	97.31	10.602	4758.	285533.	6852806.	530.14
4.0	4.538	239.6	22.	19.67	103.9	10.995	4935.	296108.	7106614.	549.77
4.5	4.836	255.3	20.6	20.96	110.7	11.388	5111.	306684.	7360422.	569.4
5.0	5.14	271.4	19.4	22.28	117.6	11.781	5287.	317259.	7614230.	589.04

OST TO CONSTRUCT 12" CAST IRON WATER PIPE LINES.

	—Cost per— foot.	mile.
EAD—Depth, average, 2". Amount per joint, 18 lbs.; per foot, 1.5 lbs. COST @ 5c. per lb. in the work	$0.075	$396.00
HEMP—Amount per joint, average, 0.9 lb.; per foot, 0.075 lb. COST @ 7c. per lb. in the work	0.0052	27.46
EXCAVATION—Amount, 14 cu. ft., per foot., including "bell holes" (4' cover). COST, including RE-FILLING and TAMPING	0.25	1320.00
CARTAGE—Average haul, 2 miles, 4 pipes on truck	0.023	121.44
PIPE LAYING—Under average difficulties, with proper tools	0.08	422.40
Foreman, Timekeeper, Watchman, Insurance, Repairs, Incidentals	0.12	633.60
AVERAGE COST in CITY STREETS, exclusive of pipe and repaving	$0.5532	$2920.90
Or approximately	$0.55	$2900.
AVERAGE COST in FIELDS and on COUNTRY ROADS	$0.49	$2587.

For COST to RESTORE PAVEMENTS, see Table No. 132

FLANGED PIPE—Standard dimensions. See Table No. 134.

Area 12" Pipe, 0.7854 sq. ft. Contents per foot in length, 5.87 U. S. *Gallons.*

Table No. 128.

DIAMETER 10 INCHES.

Table Showing loss of head and pressure and discharging capa[city] for different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Sq. in. in 1000 feet	Mile	Discharge in Cub. Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day
.1	0.0008	0.04	127942	0.003	0.018	0.054	25.	1469.	35251.
.2	0.0027	0.14	36737	0.012	0.062	0.109	49.	2937.	70501.
.3	0.0056	0.30	17711	0.024	0.129	0.163	73.	4406.	105752.
.4	0.0095	0.5	10551	0.041	0.217	0.218	98.	5875.	141003.
.5	0.014	0.75	7061.	0.061	0.324	0.272	122.	7343.	176254.
.6	0.02	1.04	5086.	0.085	0.449	0.327	147.	8812.	211504.
.7	0.026	1.37	3853.	0.112	0.594	0.381	171.	10281.	246755.
.8	0.033	1.74	3030.	0.143	0.755	0.436	196.	11750.	282006.
.9	0.0408	2.15	2451.	0.177	0.934	0.49	220.	13218.	317256.
1.0	0.0493	2.6	2027.	0.214	1.129	0.545	245.	14687.	352507.
1.1	0.0585	3.09	1708.	0.254	1.34	0.599	269.	16156.	387757.
1.2	0.0685	3.62	1461.	0.297	1.567	0.654	293.	17625.	423008.
1.3	0.079	4.18	1265.	0.343	1.81	0.709	318.	19094.	458259.
1.4	0.0903	4.77	1107.	0.392	2.068	0.763	342.	20562.	493509.
1.5	0.1023	5.4	977.4	0.444	2.34	0.818	367.	22031.	528760.
1.6	0.1149	6.07	870.2	0.498	2.63	0.872	391.	23500.	564011.
1.7	0.1281	6.77	780.3	0.556	2.93	.927	416.	24969.	599262.
1.8	0.1421	7.5	704.	0.616	3.25	0.981	440.	26438.	634512.
1.9	0.1566	8.27	638.7	0.679	3.58	1.036	465.	27906.	669763.
2.0	0.172	9.08	581.6	0.745	3.94	1.091	489.	29375.	705014.
2.1	0.1878	9.91	532.6	0.814	4.3	1.145	514.	30844.	740264.
2.2	0.2042	10.78	489.8	0.885	4.67	1.199	538.	32313.	775515.
2.3	0.2212	11.68	452.1	0.959	5.06	1.254	563.	33781.	810766.
2.4	0.2388	12.61	418.7	1.035	5.47	1.308	587.	35250.	846017.
2.5	0.2566	13.55	389.7	1.112	5.87	1.363	611.	36719.	881267.
2.6	0.2754	14.54	363.2	1.194	6.3	1.418	636.	38188.	916518.
2.7	0.2947	15.56	339.3	1.278	6.59	1.472	660.	39657.	951769.
2.8	0.3147	16.61	317.8	1.364	7.2	1.527	685.	41125.	987019.
2.9	0.3352	17.7	298.4	1.453	7.67	1.581	709.	42494.	1022270.
3.0	0.3563	18.81	280.7	1.544	8.15	1.636	734.	44063.	1057521.
3.1	0.378	19.96	264.6	1.638	8.65	1.69	758.	45532.	1092772.
3.2	0.4	21.13	249.9	1.735	9.16	1.745	783.	47000.	1128022.
3.3	0.4229	22.33	236.5	1.833	9.68	1.799	807.	48469.	1163273.
3.4	0.4463	23.56	224.1	1.935	10.21	1.854	832.	49938.	1198524.
3.5	0.4702	24.83	212.7	2.038	10.76	1.908	856.	51407.	1233774.
3.6	0.4946	26.12	202.2	2.144	11.32	1.963	881.	52876.	1269025.
3.7	0.5197	27.44	192.4	2.253	11.89	2.018	905.	54344.	1304276.
3.8	0.5452	28.79	183.4	2.363	12.48	2.072	930.	55813.	1339526.
3.9	0.5713	30.16	175.	2.476	13.08	2.127	954.	57282.	1374777.
4.0	0.5979	31.57	167.2	2.592	13.69	2.181	979.	58751.	1410028.
4.1	0.6251	33.	160.	2.71	14.31	2.236	1003.	60219.	1445279.
4.2	0.6528	34.47	153.2	2.83	14.94	2.29	1028.	61688.	1480529.
4.3	0.6812	35.96	146.8	2.952	15.59	2.34	1052.	63157.	1515780.
4.4	0.7099	37.48	140.9	3.077	16.25	2.399	1077.	64626.	1551031.
4.5	0.7392	39.03	135.3	3.204	16.92	2.454	1101.	66095.	1586281.
4.6	0.769	40.6	130.	3.333	17.6	2.508	1126.	67563.	1621532.
4.7	0.7994	42.2	125.1	3.465	18.29	2.563	1150.	67032.	1656783.
4.8	0.8302	43.83	120.5	3.599	19.	2.617	1174.	70501.	1692034.
4.9	0.8616	45.49	116.1	3.735	19.72	2.672	1199.	71970.	1727284.
5.0	0.8935	47.18	111.9	3.873	20.45	2.727	1223.	73438.	1762535.
5.5	1.061	56.01	94.2	4.598	24.28	2.999	1346.	80782.	1938789.
6.0	1.241	65.5	80.6	5.378	28.39	3.272	1468.	88126.	2115042.
6.5	1.433	75.65	69.7	6.211	32.79	3.545	1591.	95470.	2291296.
7.0	1.639	86.45	61.	7.097	37.47	3.817	1713.	102814.	2467549.
7.5	1.854	97.88	53.9	8.036	42.43	4.09	1835.	110158.	2643803.
8.0	2.083	109.9	48.	9.026	47.65	4.363	1958.	117502.	2820056.
8.5	2.323	122.6	43.	10.07	53.15	4.636	2080.	124846.	2996310.
9.0	2.574	135.9	38.8	11.16	58.91	4.908	2203.	132190.	3172563.
[illegible]5	2.837	149.8	35.2	12.3	64.93	5.181	2325.	139534.	3348817.
[illegible]	3.111	164.3	32.1	13.4	71.21	5.454	2447.	146877.	3525071.

Table No. 128. (Continued.)

DIAMETER 10 INCHES.

ble Showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile	One Foot in	Pressure Lost in Pounds per Sq. in. in 1000 feet	Mile	Discharge in Cub. Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day	Miners Inches 4-inch Head.
3.397	179.4	29.4	14.72	77.75	5.726	2570.	154221.	3701324.	286.33
3.694	195.	27.	16.01	84.54	5.960	2692.	161565.	3877578.	299.97
4.	211.3	24.9	17.34	91.58	6.272	2815.	168909.	4053831.	313.6
4.32	228.1	23.1	18.73	98.87	6.544	2937.	176253.	4230085.	327.24
4.649	245.5	21.5	20.15	106.4	6.817	3059.	183597.	4406338.	340.87
4.989	263.4	20.	21.63	114.2	7.09	3182.	190941.	4582592.	354.51
5.34	282.	18.7	23.15	122.2	7.363	3304.	198285.	4758845.	368.14
5.7	301.	17.5	24.71	130.5	7.635	3427.	205629.	4935099.	381.78
6.073	320.7	16.4	26.33	139.	7.908	3549.	212973.	5111352.	395.41
6.456	340.8	15.4	27.98	147.7	8.181	3672.	220316.	5287606.	409.05

OST TO CONSTRUCT 10" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile.
LEAD—Depth, average, 1⅞"; amount per joint, 15 lbs.; per foot, 1.25 lbs. COST, @ 5c. per lb. in the work	$0.0625	$330.00
HEMP—Amount per joint, average, 0.8 lb.; per foot, 0.066 lb. COST, @ 7c. per lb the work	0.0046	24.29
EXCAVATION—Amount, 13.5 cu. ft. per foot, including bell holes (4' cover). COST, including RE-FILLING and TAMPING	0.22	1161.60
CARTAGE—Average haul, 2 miles, 5 pipes on truck	0.0187	98.74
PIPE LAYING—Under average difficulties, with proper tools	0.06	316.80
FOREMAN, Timekeeper, Watchman, Insurance, Repairs, Incidentals	0.10	528.00
AVERAGE COST in City Streets, exclusive of pipe and re-paving	$0.4658	$2459.43
or approximately	$0.47	$2460
AVERAGE COST, in fields, on country roads, or in unpaved streets of small municipalities, where FEW repairs to existing drain pipes and other structures are required	$0.42	$2217.60
or approximately	$0.42	$2200

For COST of PIPE per pound at any price per net or gross ton, see Table No. 133.

For COST for FREIGHT and CARTAGE, see Table No. 133.

For COST to RESTORE PAVEMENTS see Table No. 132.

FLANGED PIPE—Standard dimensions, see Table No. 134.

Area 10" pipe, 0.5454 sq. ft. Contents per foot in length, *4.08 U. S. gallons.*

Table No. 129.

DIAMETER 8 INCHES.

Table showing loss of head and pressure and discharging capa
different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot In	Pressure Lost in Pounds per Sq. in. in 1000 feet.	Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	Per Hour.	Per Day.
.1	0.001	0.06	97042.	0.004	0.024	0.035	16.	940.	22560
.2	0.0036	0.19	27798	0.016	0.082	0.070	31.	1880.	45121
.3	0.0075	0.39	13585.	0.032	0.171	0.105	47.	2820.	67681
.4	0.0125	0.66	7988.	0.054	0.287	0.140	63.	3760.	90241
.5	0.0187	0.99	5342.	0.081	0.426	0.174	78.	4700.	112802
.6	0.026	1.37	3847.	0.113	0.595	0.209	94.	5640.	135362
.7	0.0343	1.81	2915.	0.149	0.785	0.244	110.	6580.	157922
.8	0.0436	2.3	2292.	0.189	0.998	0.279	125.	7520.	180482
.9	0.0539	2.85	1855.	0.234	1.234	0.314	141.	8460.	203043
1.0	0.0652	3.44	1534.	0.283	1.493	0.349	157.	9400.	225603
1.1	0.0774	4.09	1292.	0.335	1.771	0.383	172.	10340.	248163
1.2	0.0905	4.78	1105.	0.392	2.071	0.418	188.	11280.	270723
1.3	0.1045	5.52	956.7	0.453	2.392	0.453	204.	12220.	293283
1.4	0.1195	6.31	837.2	0.518	2.734	0.488	219.	13160.	315844
1.5	0.1353	7.14	739.5	0.586	3.094	0.523	235.	14100.	338404
1.6	0.1519	8.02	658.4	0.658	3.476	0.558	251.	15040.	360964
1.7	0.1694	8.95	590.3	0.734	3.877	0.593	266.	15980.	383525
1.8	0.1878	9.91	532.6	0.814	4.297	0.628	282.	16920.	406085
1.9	0.207	10.93	483.2	0.897	4.738	0.663	298.	17860.	428645
2.0	0.2273	12.	440.	0.985	5.202	0.698	313.	18800.	451206
2.1	0.2482	13.1	402.9	1.076	5.68	0.733	329.	19740.	473766
2.2	0.2699	14.25	370.5	1.17	6.177	0.767	345.	20680.	496326
2.3	0.2924	15.44	342.	1.267	6.692	0.802	360.	21620.	518887
2.4	0.3157	16.67	316.8	1.368	7.225	0.837	376.	22560.	541447
2.5	0.3392	17.91	294.8	1.47	7.763	0.872	392.	23500.	564007
2.6	0.364	19.22	274.7	1.578	8.33	0.907	407.	24440.	586568
2.7	0.3896	20.57	256.7	1.689	8.916	0.942	423.	25380.	609128
2.8	0.416	21.96	240.4	1.803	9.519	0.977	439.	26320.	631688
2.9	0.443	23.39	225.7	1.92	10.14	1.012	454.	27260.	654248
3.0	0.4709	24.86	212.3	2.041	10.78	1.047	470.	28200.	676809
3.1	0.4995	26.38	200.2	2.165	11.43	1.082	486.	29140.	699369
3.2	0.5289	27.93	189.1	2.293	12.11	1.116	501.	30080.	721929
3.3	0.5591	29.52	178.9	2.423	12.79	1.151	517.	31020.	744490
3.4	0.5899	31.15	169.5	2.557	13.5	1.186	533.	31960.	767050
3.5	0.6215	32.82	160.9	2.694	14.22	1.221	548.	32900.	789610
3.6	0.6538	34.52	152.9	2.834	14.96	1.256	564.	33840.	812171
3.7	0.6869	36.27	145.6	2.977	15.73	1.291	579.	34780.	834731
3.8	0.7207	38.05	138.8	3.124	16.49	1.326	595.	35720.	857291
3.9	0.7552	39.87	132.4	3.273	17.28	1.361	611.	36660.	879852
4.0	0.7904	41.73	126.5	3.426	18.09	1.396	626.	37600.	902412
4.1	0.8263	43.63	121.	3.582	18.91	1.431	642.	38540.	924972
4.2	0.8629	45.56	115.9	3.74	19.75	1.466	658.	39480.	947532
4.3	0.9003	47.54	111.1	3.902	20.6	1.5	674.	40420.	970093
4.4	0.9383	49.54	106.6	4.067	21.47	1.535	689.	41360.	992653
4.5	0.9771	51.59	102.4	4.235	22.36	1.57	705	42300.	1015213
4.6	1.016	53.67	98.3	4.406	23.26	1.605	721.	43240.	1037774
4.7	1.057	55.79	94.6	4.58	24.18	1.64	736.	44180.	1060334
4.8	1.098	57.93	91.1	4.757	25.12	1.675	752.	45120.	1082894
4.9	1.139	60.13	87.8	4.937	26.07	1.71	767.	46060.	1105455
5.0	1.181	62.36	84.6	5.119	27.03	1.745	783.	47000.	1128015
5.5	1.402	74.03	71.3	6.078	32.09	1.919	862	51700.	1240816
6.0	1.64	86.59	60.9	7.108	37.53	2.094	940.	56400.	1353618
6.5	1.894	100.	52.8	8.21	43.35	2.268	1018.	61100.	1466420
7.0	2.164	114.3	46.2	9.381	49.53	2.443	1097.	65800	1579221
7.5	2.451	129.4	40.8	10.62	56.08	2.617	1175.	70500.	1692023
8.0	2.752	145.3	36.3	11.93	62.99	2.792	1253	75201.	1804824
8.5	3.07	162.1	32.5	13.31	70.25	2.967	1332.	79901.	1917626
[illegible]	3.402	179.6	29.3	14.71	77.87	3.141	1410.	84601.	2030427
[illegible]	[illegible]	198.	26.5	16.25	85.83	3.316	1488.	89301.	2143229
[illegible]	[illegible]	217.1	24.3	17.83	94.13	3.491	1567.	94001.	22560

Table No. 129. (Continued.)

DIAMETER 8 INCHES.

able showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

[illegible]	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Head Lost … In Feet per Mile.	One Foot In	Pressure Lost in Pounds per Sq. In. in 1000 feet	Pressure Lost … Mile	Discharge in Cubic Feet per Second.	United States Gall's Per Minute.	United States Gall's Per Hour.	United States Gall's Per Day.	Miners Inches 4-Inch Head.
5	4.49	237.1	22.2	19.46	102.8	3.665	1645.	98701.	2368832.	183.26
0	4.888	257.8	20.4	21.16	111.7	3.830	1723.	103401.	2481633.	191.98
5	5.289	279.3	18.9	22.93	121.1	4.014	1802.	108101.	2594435.	200.71
0	5.71	301.5	17.5	24.75	130.7	4.188	1880.	112801.	2707236.	209.44
5	6.146	324.5	16.2	26.54	140.7	4.363	1958.	117501.	2820038.	218.16
0	6.595	348.2	15.1	28.59	150.9	4.537	2037.	122201.	2932839.	226.89
5	7.058	372.7	14.1	30.6	161.6	4.712	2115.	126901.	3045641.	235.62
0	7.585	397.8	13.2	32.06	172.4	4.886	2193.	131601.	3158443.	244.34
5	8.028	423.9	12.4	34.8	183.7	5.060	2272.	136301.	3271244.	253.07
0	8.532	450.5	11.7	36.99	195.3	5.236	2350.	141001.	3384046.	261.8

COST TO CONSTRUCT 8" CAST IRON WATER PIPE LINES.

	Cost per Foot.	Cost per Mile.
LEAD—Depth, average, 1⅞". Amount per joint, 12 lbs.; per foot, 1 lb. COST @ 5c. per lb. in the work	$0.05	$264.00
HEMP—Amount per joint, average, 0.6 lb. COST @ 7c. per lb. in the work	0.0035	18.48
EXCAVATION—Amount, 12 cu. ft., per foot, including "bell-holes" (4' cover). COST, including RE-FILLING and TAMPING	0.18	950.40
CARTAGE—Average haul, 2 miles, 6 pipe on truck	0.0156	82.37
PIPE LAYING—Under average difficulties, with proper tools	0.04	211.20
FOREMAN, Timekeeper, Watchman, Insurance, Repairs, Incidentals	0.08	422.40
AVERAGE COST IN City Streets, exclusive of pipe and repaving	$0.3691	$1948.85
Or approximately	$0.37	$1950.
AVERAGE COST in fields, on country roads, or in unpaved streets of small municipalities, where few repairs to existing drains, pipes or other structures are required	$0.33	$1742.

For COST of PIPE per pound at any price per net or gross ton, see Table No. 133.

For COST for FREIGHT or CARTAGE, see Table No. 133.

For COST to RESTORE PAVEMENTS, see Table 132.

FLANGED PIPE—Standard dimensions. See Table No. 134.

Area 8" pipe, 0.349 sq. ft. Contents per foot in length, *2.61 U. S. gallons.*

Table No. 130.

DIAMETER 6 INCHES.

Table Showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	In Feet per Mile.	One Foot In	Pressure Lost in Pounds per Sq. in. in 1000 feet	Pressure Lost in Pounds per Sq. in. in Mile	Discharge in Cub. Feet per Second.	United States Gall's Per Minute.	United States Gall's Per Hour.	United States Gall's Per Day	Miners Inches 4-in. Head
.1	0.0013	0.06	79386.	0.005	0.03	0.02	8.8	529.	12690.	[illegible]
.2	0.0052	0.27	19404.	0.022	0.12	0.039	17.6	1057.	25380.	[illegible]
.3	0.0107	0.57	9352.	0.046	0.25	0.059	26.4	1586.	38069.	[illegible]
.4	0.0179	0.95	5573.	0.078	0.41	0.078	35.2	2115.	50759.	[illegible]
.5	0.0268	1.42	3729.	0.116	0.61	0.098	44.	2644.	63449.	[illegible]
.6	0.0372	1.97	2686.	0.162	0.85	0.118	52.8	3172.	76139.	[illegible]
.7	0.0491	2.6	2035.	0.213	1.13	0.137	61.6	3701.	88829.	[illegible]
.8	0.0625	3.3	1600.	0.271	1.43	0.157	70.4	4230.	101518.	[illegible]
.9	0.0773	4.08	1294.	0.335	1.77	0.176	79.2	4758.	114208.	[illegible]
1.0	0.0934	4.93	1071.	0.405	2.14	0.196	88.	5287.	126898.	[illegible]
1.1	0.1104	5.85	902.1	0.481	2.54	0.215	97.	5816.	139587.	[illegible]
1.2	0.1296	6.85	777.3	0.562	2.97	0.235	106.	6345.	152277.	[illegible]
1.3	0.1498	7.91	667.8	0.649	3.43	0.255	115.	6874.	164967.	[illegible]
1.4	0.1711	9.04	584.4	0.742	3.92	0.274	123.	7402.	177657.	[illegible]
1.5	0.1938	10.23	516.2	0.84	4.43	0.294	132.	7931.	190347.	[illegible]
1.6	0.2176	11.49	459.6	0.943	4.98	0.314	141.	8460.	203036.	[illegible]
1.7	0.2427	12.82	412.1	1.052	5.56	0.333	150.	8989.	215726.	[illegible]
1.8	0.269	14.2	371.8	1.166	6.16	0.353	159.	9517.	228416.	[illegible]
1.9	0.2965	15.66	337.3	1.285	6.79	0.373	167.	10046.	241106.	[illegible]
2.0	0.3256	17.19	307.1	1.411	7.45	0.392	176.	10575.	253795.	[illegible]
2.1	0.3555	18.77	281.3	1.541	8.14	0.412	185.	11104.	266485.	[illegible]
2.2	0.3866	20.41	258.7	1.676	8.85	0.431	194.	11632.	279175.	21.6
2.3	0.4189	22.12	238.7	1.816	9.59	0.451	203.	12161.	291865.	[illegible]
2.4	0.4522	23.88	221.1	1.96	10.35	0.471	211.	12689.	304544.	[illegible]
2.5	0.4859	25.66	205.8	2.106	11.12	0.49	220.	13218.	317244.	[illegible]
2.6	0.5214	27.53	191.8	2.26	11.93	0.51	229.	13747.	329934.	[illegible]
2.7	0.5581	29.47	179.2	2.419	12.77	0.53	238.	14276.	342624.	[illegible]
2.8	0.5959	31.46	167.8	2.583	13.64	0.549	247.	14805.	355316.	[illegible]
2.9	0.6347	33.51	157.6	2.751	14.53	0.569	256.	15333.	368003.	[illegible]
3.0	0.6746	35.62	148.2	2.924	15.44	0.589	264.	15862.	380693.	[illegible]
3.1	0.7156	37.79	139.7	3.102	16.38	0.608	273.	16391.	393383.	[illegible]
3.2	0.7578	40.01	132.	3.284	17.34	0.628	282.	16920.	406073.	[illegible]
3.3	0.8009	42.29	124.9	3.472	18.33	0.647	291.	17448.	418762.	[illegible]
3.4	0.8451	44.62	118.3	3.663	19.34	0.667	300.	17977.	431452.	[illegible]
3.5	0.8904	47.01	112.3	3.859	20 38	0.687	308.	18506.	444142.	[illegible]
3.6	0.9366	49.45	106.8	4.06	21.44	0.706	317.	19034.	456832.	[illegible]
3.7	0.9841	51.96	101.6	4.265	22.52	0.726	326.	19563.	469522.	[illegible]
3.8	1.033	54.51	96.8	4.475	23.63	0.745	335.	20092.	482211.	[illegible]
3.9	1.082	57.12	92.4	4.689	24.76	0.765	344.	20621.	494901.	[illegible]
4.0	1.132	59.78	88.3	4.908	25.91	9.785	352.	21150.	507591.	[illegible]
4.1	1.184	62.5	84.4	5.131	27.09	0.804	361.	21678.	520281.	[illegible]
4.2	1.236	65.27	80.8	5.359	28.29	0.824	370.	22207.	532970.	[illegible]
4.3	1.29	68.1	77.5	5.59	29.52	0.844	379.	22736.	545660.	[illegible]
4.4	1.344	70.97	74.4	5.827	30.76	0.863	388.	23265.	558350.	[illegible]
4.5	1.4	73.9	71.4	6.067	32.03	0.883	397.	23793.	571040.	[illegible]
4.6	1.456	76.88	68.6	6.312	33.33	0.903	405.	24322.	583729.	[illegible]
4.7	1.514	79.92	66.	6.561	34.64	0.922	414.	24851.	596419.	[illegible]
4.8	1.573	83.01	63.6	6.814	35.98	9.942	423.	25379.	609109.	[illegible]
4.9	1.631	86.14	61.2	7.072	37.34	0.962	432	25908.	621799.	48.1
5.0	1.692	89.34	59.1	7.334	38.72	0.981	441.	26437.	634489.	[illegible]
5.5	2.01	106.1	49.7	8.704	45.97	1.079	485.	29081.	697937.	[illegible]
6.0	2.35	124.	42.5	10.19	53.8	1.178	529	31724.	761386	[illegible]
6.5	2.713	143.3	36.8	11.76	62.1	1.271	573.	34368.	824835.	[illegible]
7.0	3.101	163.7	32.2	13.44	70.96	1.374	617.	37012.	888284.	[illegible]
7.5	3.51	185.4	28.4	15.22	80.34	1.472	661.	39656.	951733.	[illegible]
8.0	3.943	208.2	25.3	17.09	90.24	1.57	705.	42299.	1015182.	[illegible]
8.5	4.397	232.2	22.7	19.06	100.7	1.668	749.	44943.	1078630.	[illegible]
9.0	4.874	257.3	20.5	21.13	111.5	1.767	793.	47587.	1142079.	[illegible]
9.5	5.38	283.6	19.	23.27	123.	1.865	837.	50230.	1205528.	[illegible]
10.0	5.892	311.2	16.9	25.54	134.8	1.963	881.	52874.	1268977.	[illegible]

Table No. 130. (Continued.)

DIAMETER 6 INCHES.

le Showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

Head Lost or Grade Required to Produce Veloc'ty.			Pressure Lost in Pounds per Sq. in. in		Discharge in				
In Feet per		One Foot In			Cub. Feet per Second.	United States Gall's			Miners Inches 4-inch Head.
100 Ft.	Mile		1000 feet	Mile		Per Minute.	Per Hour.	Per Day	
6.433	339.6	15.5	27.88	147.2	2.061	925.	55516.	1332420	103.08
6.995	369.8	14.3	30.32	160.1	2.159	969.	58161.	1395875.	107.99
7.577	400.1	13.2	32.84	173.4	2.257	1013.	60805.	1459328.	112.9
8.18	431.9	12.2	35.46	187.2	2.356	1057.	63449.	1522772.	117.8
8.804	464.9	11.[illegible]	38.16	201.5	2.454	1102.	66092.	1586221	122.71
9.448	498.8	10.5	40.95	216.2	2.552	1146.	68736.	1649670.	127.62
10.11	533.9	9.8	43.83	231.4	2.65	1190.	71380.	1713119.	132.53
10.70	570.	9.2	46.79	247.	2.748	1234.	74024.	1776568.	137.44
11.5	607.2	8.6	49.82	263.2	2.846	1278.	76667.	1840017.	142.35
12.23	645.4	8.1	52.99	279.8	2.945	1322.	79311.	1903465.	147.26

ST TO CONSTRUCT 6" CAST IRON WATER PIPE LINES.

	Cost per Foot.	Cost per Mile.
EAD—Depth, average, 1⅞". Amount per joint, 9 lbs.; per foot, 0.75 lb. COST @ 5c. per lb. in the work	$0.0375	$198.00
EMP—Amount per joint, average, 0.4 lb.; per foot, 0.033 lb. COST @ 7c. per lb. in the work	0.0023	12.14
XCAVATION—Amount, 10 cu. ft., per foot, including "bell-holes" (4' cover). COST, including RE-FILLING and TAMPING	0.15	792.00
ARTAGE—Average haul, 2 miles, 10 pipe on truck	0.0094	49.63
IPE LAYING—Under average difficulties, with proper tools	0.0275	145.20
OREMAN, Timekeeper, Watchman, Insurance, Repairs, Incidentals	0.06	316.80
AVERAGE COST in City Streets, exclusive of pipe and repaving	$0.2867	$1513.78
Or approximately	$0.29	$1500.
AVERAGE COST in small municipalities, where few repairs to existing drains, pipes or other structures are required	$0.26	$1373.

For COST for PIPE per pound at anyprice, net or gross on, see Table No. 133.

For COST for FREIGHT or cartage, see Table No. 133.

For COST to RESTORE PAVEMENTS, see Table No. 32.

Flanged pipe, standard dimensions, see Table No. 134.

Area, 6" pipe, 0.196 sq. ft. Contents per foot in length, 49 U. S. gallons.

Table No. 131.

DIAMETER 4 INCHES.

Table showing loss of head and pressure and discharging capacity different velocities for Cast Iron Pipe Lines.

Velocity in ft. per second.	Head Lost or Grade Required to Produce Velocity. In Feet per 100 Ft.	Mile.	One Foot in	Pressure Lost in Pounds per sq. in. in 1000 feet.	Mile	Discharge in Cubic Feet per second.	United States Gall's Per Minute.	Per Hour.	Per Day.
.1	0.0025	0.13	40700.	0.011	0.06	0.009	3.9	235	5640
.2	0.0088	[illegible]	[illegible]	0.0387	0.2	0.0177	7.8	470	11280
.3	0.018	0.94	5661.	0.077	0.41	0.0261	11.7	705	16815
.4	0.03	1.57	3360.	0.1300	0.68	0.035	15.7	940	22560
.5	0.045	2.35	2246.	0.193	1.02	0.043	19.6	1175	[illegible]
.6	0.062	3.26	1618.	0.268	1.41	0.052	23.5	1410	[illegible]
.7	0.081	4.31	1226.	0.351	1.85	0.061	27.4	1645	39479
.8	0.104	5.48	964.	0.45	2.37	0.069	31.3	1880	45119
.9	0.129	6.77	780.	0.556	2.93	0.078	35.2	2115	50759
1.0	0.156	8.13	645.	0.672	3.44	0.087	39.2	2350	56397
1.1	0.184	9.7	543.	0.7980	4.21	0.096	43.1	2585	62037
1.2	0.215	11.4	465.	0.9292	4.38	0.105	47.	2820	67677
1.3	0.249	13.1	402.	1.077	5.69	0.113	50.9	3055	73317
1.4	0.284	15.	352.	1.231	6.5	0.122	54.9	3290	78956
1.5	0.322	17.	311.	1.394	7.36	0.131	58.7	3525	84596
1.6	0.361	19.1	277.	1.560	8.27	0.14	62.7	3759	[illegible]
1.7	0.403	21.3	248.	1.746	9.22	0.148	66.6	3995	[illegible]
1.8	0.446	23.6	224.	1.930	10.22	0.157	70.5	4230	101516
1.9	0.492	26.	203.	2.133	11.26	0.166	74.4	4465	107155
2.0	0.540	28.5	185.	2.34	12.35	0.175	78.3	4700	[illegible]
2.1	0.590	31.1	170.	2.556	13.49	0.183	82.2	4935	118434
2.2	0.641	33.8	156.	2.778	14.67	0.192	86.2	5170	124076
2.3	0.694	36.7	144.	3.009	15.89	0.201	90.1	5405	129714
2.4	0.750	39.6	133.	3.249	17.15	0.209	94.	5640	135354
2.5	0.807	42.6	124.	3.497	18.46	0.218	97.9	5875	[illegible]
2.6	0.866	45.7	116.	3.752	19.81	0.227	101.8	6110	[illegible]
2.7	0.927	48.9	108.	4.016	21.2	0.236	105.7	6345	[illegible]
2.8	0.990	52.2	101.	4.287	22.64	0.244	109.7	6579	[illegible]
2.9	1.054	55.6	95.	4.567	24.11	0.253	113.6	6814	[illegible]
3.0	1.12	59.1	89.3	4.854	25.63	0.262	117.5	7050	[illegible]
3.1	1.188	62.7	84.2	5.148	27.19	0.271	121.4	7285	[illegible]
3.2	1.258	66.4	79.6	5.452	28.79	0.279	125.3	7520	[illegible]
3.3	1.329	70.2	75.3	5.757	30.4	0.288	129.2	7755	[illegible]
3.4	1.403	74.1	71.3	6.081	32.11	0.297	133.1	7990	[illegible]
3.5	1.479	78.1	67.7	6.407	33.83	0.305	137.	8225	[illegible]
3.6	1.555	82.1	64.3	6.74	35.59	0.314	141.	8460	[illegible]
3.7	1.634	86.3	61.2	7.081	37.39	0.323	145.	8695	[illegible]
3.8	1.714	90.5	58.3	7.429	39.22	0.332	149.	8930	[illegible]
3.9	1.796	94.8	55.7	7.784	41.1	0.34	153.	9165	[illegible]
4.0	1.88	99.3	53.2	8.147	43.02	0.349	157.	9400	[illegible]
4.1	1.965	103.7	50.9	8.518	44.98	0.358	161.	9635	[illegible]
4.2	2.052	108.2	48.7	8.895	46.97	0.367	164.	9870	[illegible]
4.3	2.141	113.1	46.7	9.28	49.	0.375	168.	10105	[illegible]
4.4	2.232	117.8	44.8	9.67	51.07	0.384	172.	10340	[illegible]
4.5	2.324	122.7	43.0	10.07	53.18	0.393	176.	10575	[illegible]
4.6	2.418	127.6	41.4	10.48	55.32	0.401	180	10810	[illegible]
4.7	2.513	132.7	39.8	10.89	57.51	0.41	184.	11045	[illegible]
4.8	2.61	137.8	38.3	11.31	59.73	0.419	188.	11280	[illegible]
4.9	2.709	143.1	37.0	11.74	61.99	0.428	192.	11515	[illegible]
5.0	2.809	148.3	35.6	12.17	64.28	0.436	196.	11750	282387
5.5	3.335	176.1	30.0	14.45	76.31	0.48	215.	12704	[illegible]
6.0	3.9	205.9	25.6	16.9	89.25	0.524	235.	14099	[illegible]
6.5	4.505	237.8	22.2	19.52	103.1	0.567	255.	15274	[illegible]
7.0	5.148	271.8	19.4	22.31	117.8	0.611	274.	16449	[illegible]
7.5	5.828	307.7	17.2	25.26	133.3	0.655	294.	17624	[illegible]
8.0	6.560	345.6	15.3	28.37	149.8	0.698	313.	18799	[illegible]
8.5	7.401	385.5	13.7	31.64	167.1	0.742	333.	19974	[illegible]
[illegible]	8.202	427.2	12.4	35.07	185.2	0.785	352.	[illegible]	[illegible]
[illegible]	8.797	464.5	11.4	38.12	201.3	0.829	372.	[illegible]	[illegible]
[illegible]	[illegible]	516.5	10.2	42.39	223.3	0.873	392.	23499	[illegible]

Table No. 131. (Continued.)

DIAMETER 4 INCHES.

showing loss of head and pressure and discharging capacity for different velocities for Cast Iron Pipe Lines.

ead Lost or Grade Required to Produce Velocity.			Pressure Lost in Pounds per Sq. in. in		Discharge in				
In Feet per		One Foot In			Cubic Feet per Second.	United States Gall's			Miners Inches 4-inch Head.
Ft.	Mile.		1000 feet.	Mile		Per Minute.	Per Hour.	Per Day.	
.68	563.9	9.4	46.29	244.4	0.916	411.	24674	592174	45.81
.604	612.7	8.6	50.29	265.6	0.96	431.	25849	620372	48.
.58	664.2	7.9	54.52	287.9	1.00	450.	27024	648571	50.17
.58	717.1	7.4	58.86	310.8	1.047	470.	28198	676770	52.36
.62	771.8	6.8	63.35	334.5	1.091	490.	29373	704969	54.54
.69	828.2	6.4	67.98	359.	1.134	509.	30548	733167	56.72
.9	886.4	6.0	72.76	384.2	1.178	529.	31723	761366	58.90
.92	946.4	5.6	77.68	410.2	1.221	548	32898	789565	61.08
.09	1000.	5.2	82.75	436.9	1.265	568.	34073	817764	63.26
.29	1071.5	4.9	87.96	464.4	1.309	587.	35249	845962	65.45
.65	1407.	3.7	115.5	610.	1.527	685.	41124	986956	76.35
.06	1798.	2.9	147.6	779.5	1.745	783.	46998	1127949	87.26
.11	2223.	2.4	182.5	963.5	1.963	881.	52873	1268943	98.17
.9	2687.	2.0	220.6	1165.	2.182	979.	58748	1409937	109.08
.43	3190.	1.7	261.9	1383.	2.400	1077.	64623	1550930	119.98
.67	3731.	1.4	306.3	1617.	2.618	1174.	70497	1691924	130.89
.62	4310.	1.2	353.7	1868.	2.836	1272.	76372	1832918	141.8
.27	4924.	1.1	404.2	2134.	3.054	1370.	82247	1973912	152.71
	5280.	1.0	433.4	2288.	3.176	1426.	85536	2052869	158.81

TO CONSTRUCT 4" CAST IRON WATER PIPE LINES.

	Cost per foot.	mile
D—Depth, average, 1⅞"; amount per t, 6 lbs.; per foot, 0.5 lbs. COST, @ per lb. in the work	$0.025	$132.00
P—Amount per joint, average, 0.2 lb.; foot, 0.0166 lb. COST, @ 7c. per lb. he work	0.00117	6.18
VATION—Amount, 8 cu. ft. per foot, uding "bell holes" (4' covers). COST, uding RE-FILLING and TAMPING	0.12	633.60
TAGE—Average haul, 2 miles; 14 pipes truck	.0.0066	34.85
LAYING—Under average difficulties, h proper tools	0.025	132.00
EMAN, Timekeeper, Watchman, Innce, Repairs, Incidentals	0.04	211.20
ERAGE COST in City Streets, exusive of pipe and re-paving	$0.21777	$1149.83
or approximately	$0.22	$1150.00
ERAGE COST in small municipalities here few repairs to existing drains, pes and other structures are required	$0.20	$1056.00

a 4" pipe, 0.087 sq. ft. Contents per foot in length, *I. S. gallons.*

COST TO RESTORE PAVEMENTS.

If pavement material cannot be replaced, use with judgment Tables No. 111 to 118 inclusive, together with other information given in this work relative to pavements. As a rule much of the material can be replaced and cost will average as follows:

Table No. 132.

Asphalt: $2.50 per sq. yd. Depends on base and thickness.

Brick: On concrete base, average of 80% of brick replaced, $ [illegible] per sq. yd.

Stone Block: On sand base, blocks and part of base replaced, $ [illegible] per sq. yd.

Macadam: Material not worn out, saved, screened and replaced, $ .15 to $ .25 per sq. yd., depending on [illegible] of stone.

[illegible]: Same as Macadam, plus labor in replacing [illegible]. Under the authors supervision 12 miles [illegible] by contract for [illegible] cents per lineal foot of [illegible] pipe lines varied from 4" to 16", and averaged [illegible]

[illegible] Not much less than Macadam on account of [illegible] amount of new material necessary. The road [illegible] screening.

[illegible] after tamping under, around and [illegible] over the pipe line, puddle all replaced [illegible]

Table No. 133.

COST FOR MATERIAL OR TRANSPORTATION

In Cents Per Pound with Equivalents in Dollars per

NET AND GROSS TON.

Net Ton.	Gross Ton.	Cts. per lb.	Net Ton.	Gross Ton.	Cts. per lb.	Net Ton.	Gross Ton.	Cts. per lb.	Net Ton.	Gross Ton.
$ 0.20	$ 0.224	.61	$12.20	$13.66	1.21	$24.20	$27.10	1.81	$36.20	$40.54
0.40	0.448	.62	12.40	13.89	1.22	24.40	27.33	1.82	36.40	40.77
0.60	0.672	.63	12.60	14.11	1.23	24.60	27.55	1.83	36.60	40.99
0.80	0.896	.64	12.80	14.34	1.24	24.80	27.78	1.84	36.80	41.22
1.00	1.12	.65	13.00	14.56	1.25	25.00	28.00	1.85	37.00	41.44
1.20	1.344	.66	13.20	14.78	1.26	25.20	28.22	1.86	37.20	41.66
1.40	1.568	.67	13.40	15.01	1.27	25.40	28.45	1.87	37.40	41.89
1.60	1.792	.68	13.60	15.23	1.28	25.60	28.67	1.88	37.60	42.11
1.80	2.016	.69	13.80	15.46	1.29	25.80	28.90	1.89	37.80	42.34
2.00	2.24	.70	14.00	15.68	1.30	26.00	29.12	1.90	38.00	42.56
2.20	2.464	.71	14.20	15.90	1.31	26.20	29.34	1.91	38.20	42.78
2.40	2.688	.72	14.40	16.13	1.32	26.40	29.57	1.92	38.40	43.01
2.60	2.912	.73	14.60	16.35	1.33	26.60	29.79	1.93	38.60	43.23
2.80	3.136	.74	14.80	16.58	1.34	26.80	30.02	1.94	38.80	43.46
3.00	3.36	.75	15.00	16.80	1.35	27.00	30.24	1.95	39.00	43.68
3.20	3.584	.76	15.20	17.02	1.36	27.20	30.46	1.96	39.20	43.90
3.40	3.808	.77	15.40	17.25	1.37	27.40	30.69	1.97	39.40	44.13
3.60	4.032	.78	15.60	17.48	1.38	27.60	30.91	1.98	39.60	44.35
3.80	4.256	.79	15.80	17.70	1.39	27.80	31.14	1.99	39.80	44.58
4.00	4.48	.80	16.00	17.92	1.40	28.00	31.36	2.00	40.00	44.80
4.20	4.704	.81	16.20	18.14	1.41	28.20	31.58	2.01	40.20	45.02
4.40	4.928	.82	16.40	18.37	1.42	28.40	31.81	2.02	40.40	45.25
4.60	5.152	.83	16.60	18.59	1.43	28.60	32.03	2.03	40.60	45.47
4.80	5.376	.84	16.80	18.82	1.44	28.80	32.26	2.04	40.80	45.70
5.00	5.60	.85	17.00	19.04	1.45	29.00	32.48	2.05	41.00	45.92
5.20	5.824	.86	17.20	19.26	1.46	29.20	32.70	2.06	41.20	46.14
5.40	6.048	.87	17.40	19.49	1.47	29.40	32.93	2.07	41.40	46.37
5.60	6.272	.88	17.60	19.71	1.48	29.60	33.15	2.08	41.60	46.59
5.80	6.496	.89	17.80	19.94	1.49	29.80	33.38	2.09	41.80	46.82
6.00	6.72	.90	18.00	20.16	1.50	30.00	33.60	2.10	42.00	47.04
6.20	6.944	.91	18.20	20.38	1.51	30.20	33.82	2.11	42.20	47.26
6.40	6.168	.92	18.40	20.61	1.52	30.40	34.05	2.12	42.40	47.49
6.60	6.392	.93	18.60	20.83	1.53	30.60	34.27	2.13	42.60	47.71
6.80	6.616	.94	18.80	21.06	1.54	30.80	34.50	2.14	42.80	47.94
7.00	6.84	.95	19.00	21.28	1.55	31.00	34.72	2.15	43.00	48.16
7.20	8.064	.96	19.20	21.50	1.56	31.20	34.94	2.16	43.20	48.38
7.40	8.288	.97	19.40	21.73	1.57	31.40	35.16	2.17	43.40	48.61
7.60	8.512	.98	19.60	21.95	1.58	31.60	35.39	2.18	43.60	48.83
7.80	8.736	.99	19.80	22.18	1.59	31.80	35.62	2.19	43.80	49.06
8.00	8.96	1.00	20.00	22.40	1.60	32.00	35.84	2.20	44.00	49.28
8.20	9.184	1.01	20.20	22.62	1.61	32.20	36.06	2.21	44.20	49.50
8.40	9.408	1.02	20.40	22.85	1.62	32.40	36.29	2.22	44.40	49.73
8.60	9.632	1.03	20.60	23.07	1.63	32.60	36.51	2.23	44.60	49.95
8.80	9.856	1.04	20.80	23.30	1.64	32.80	36.74	2.24	44.80	50.18
9.00	10.08	1.05	21.00	23.52	1.65	33.00	36.96	2.25	45.00	50.40
9.20	10.304	1.06	21.20	23.74	1.66	33.20	37.18	2.26	45.20	50.62
9.40	10.528	1.07	21.40	23.97	1.67	33.40	37.41	2.27	45.40	50.85
9.60	10.752	1.08	21.60	24.19	1.68	33.60	37.63	2.28	45.60	51.07
9.80	10.976	1.09	21.80	24.42	1.69	33.80	37.86	2.29	45.80	51.30
10.00	11.20	1.10	22.00	24.64	1.70	34.00	38.08	2.30	46.00	51.52
10.20	11.42	1.11	22.20	24.86	1.71	34.20	38.30	2.31	46.20	51.74
10.40	11.65	1.12	22.40	25.09	1.72	34.40	38.53	2.32	46.40	51.97
10.60	11.87	1.13	22.60	25.31	1.73	34.60	38.75	2.33	46.60	52.19
10.80	12.10	1.14	22.80	25.54	1.74	34.80	38.98	2.34	46.80	52.42
11.00	12.32	1.15	23.00	25.76	1.75	35.00	39.20	2.35	47.00	52.64
11.20	12.54	1.16	23.20	25.98	1.76	35.20	39.42	2.36	47.20	52.86
11.40	12.77	1.17	23.40	26.21	1.77	35.40	39.65	2.37	47.40	53.09
11.60	12.99	1.18	23.60	26.43	1.78	35.60	39.87	2.38	47.60	53.31
11.80	13.22	1.19	23.80	26.66	1.79	35.80	40.10	2.39	47.80	53.54
12.00	13.44	1.20	24.00	26.88	1.80	36.00	40.32	2.40	48.00	53.76

Table No. 134.

[illegible] Flanged Pipe as Proposed by American Soci[ety of]
Mechanical Engineers.

Pipe Size, Inches	[illegible formula]	Thickness, [illegible]	Stress on Pipe, per square inch [illegible]	Radius of Fillet, Inches	Flange Diameter, Inches	Flange Thickness, Inches	Width, Flange Face, Inches	Bolt Circle Diameter, Inches	Number of Bolts	Bolt Size Diameter, Inches	Bolt Length, Inches	Stress on each Bolt, per square inch at Bottom of Thread [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4¾	4	[illegible]	2	825
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5¼	4	[illegible]	2¼	1,050
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	4	[illegible]	2¼	1,330
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6¾	4	[illegible]	2½	2,530
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7½	4	[illegible]	2¾	2,100
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7¾	8	[illegible]	3	1,430
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8½	8	[illegible]	3	1,630
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	9½	8	[illegible]	3	2,300
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10¾	8	[illegible]	3¼	3,200
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11¾	8	[illegible]	3¼	4,190
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	12	[illegible]	3½	3,670
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	14¼	12	[illegible]	3½	2,970
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16¼	12	[illegible]	3¾	4,250
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18¾	12	[illegible] 1	4¼	4,200
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20	16	[illegible] 1	4¼	3,660
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21¼	16	[illegible] 1	4½	4,210
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22¾	16	1 1⅛	4¾	4,340
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25	20	1 1⅛	5	4,400
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27¼	20	1 1⅛	5¼	4,320
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4 29½	29½	20	1 1⅛	5¼	5,130
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4½ 31½	31¾	24	1 1⅛	5¾	5,030
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34	28	1 1⅛	6	5,000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36	28	1⅛ 1¼	6¼	4,590
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 42	42¾	32	1¼ 1⅜	6¾	5,790
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49½	36	1¼ 1½	7¼	5,700
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56	44	1⅜ 1⅝	7¾	6,090

Table No. 135.

Actual Experiments.

ACTUAL EXPERIMENTS.—Given in order that the ıbles may be used with judgment, when old or "foul" ains are under consideration. (See Table No. 136.)

Size: diam. in inches.	Length in feet.	Head in feet lost per 100 feet.	Velocity by observation, in feet	Velocity by Riders' table, per second.	Velocity by Riders' table too small by
48	1747.2	0.3205	2.62	2.3369	10.8%
48	"	0.709	3.74	3.637	2.75%
48	"	0.1219	4.97	4.915	1.106%
48	"	0.1848	6.20	6.1885	0.18%

Made under direction of F. P. Stearns, C. E., 1885; Bos-ın cast iron conduit (coal tar coated), three years old.

o.	Size diameter in inches.	Length in feet.	Head in feet lost per 100 feet.	Velocity by Observation. in feet	Velocity by Riders' table per second.	Velocity by Riders Table. + means too great: — means too small.
.	30	20200.	0.07608	2.5	2.728	9.12% +
l.	30	"	0.0825	2.64	2.854	8.1 % +
.	30	"	0.0889	2.79	2.975	6.6 % +
.	30	"	0.0953	2.94	3.098	5.12% +
.	30	"	0.1017	3.08	3.206	4.08% +
.	30	"	0.1081	3.23	3.316	2.69% +
.	30	36700.	0.00277	0.47	0.42	10.6 %—
.	30	"	0.00831	0.73	0.79	8.2 % +
.	30	"	0.01108	0.892	0.95	6.5 % +
.	30	"	0.01385	1.045	1.058	1.2 % +
.	30	"	0.01662	1.15	1.13	1.7 %—

Experiments No. 1 to 6 inclusive, by C. G. Darrach, C. ., Phila., 1877 (about) with cast iron coated pumping ıain, two years old. Flow measured by plunger dis-lacement; 5% allowed for "slip" and 1.8 lbs. per sq. in. or 4 check valves.

Experiments No. 7 to 11 inclusive, by Freeman C. Coffin, . E., Taunton, Mass., 1895, with cast iron (coal tar oated) pumping main. Flow measured by plunger dis-lacement; 5% having been allowed for "slip." Pipe in air condition.

Size, Diam. in inches.	Length in feet.	Head in feet lost per 100 feet.	Velocity by Observation in feet	Velocity by Riders' tables. per second.	Velocity by Riders' table.
20	75,000	0.0729	2.0	2.01	0.5 % +
20	"	0.0876	2.24	2.224	0.71%—
20	"	0.1029	2.36	2.432	3.05% +
20	"	0.1186	2.52	2.642	4.84% +
20	"	0.1337	2.68	2.816	5.07% +
20	"	0.149	2.76	2.99	8.33% +
20	"	0.1645	2.92	3.159	10.18% +
20	"	0.1797	3.0	3.32	10.66% +

+Means too great. —Means too small.

Table No. 135. (Continued.)

The experiments were made by the author's friend, now dead, Chas. B. Brush, C. E., 1887, with the cast iron pumping main (coal tar coated) of the Hackensack, N. J., Water Company. The main was laid alongside railroads, in streets, across country, under rivers, etc., and had four right angles (90°) and 10 quarter (45°) bends of about 30′ radius. The pipe line had been in use 5 years, but its interior was nearly clean, at least where inspected. Flow was measured by Worthington pump plunger displacement, 5% having been allowed for slip.

Ten separate experiments by the author, with clean 16″ cast iron conduits, coal tar coated, with lengths up to 5 miles and velocities up to 6′ per second, show the observed to agree with the discharge as given in the table within less than 5% in each instance. The following experiments are given to show the necessity of not applying the tables to the discharge of "foul" or "partially air locked" pipes without proper reduction factors. See "Tuberculation," Table No. 136.

Size diameter in inches.	Length in feet.	Head in feet lost per 100 ft.	Velocity by Observation. in feet	Velocity by Riders' tables per second	Velocity by Riders' table too great by
16	25765	0.8927	5.25	6.92	31.81%
16	29580	1.419	6.82	8.45	23.9%
16	3815	4.823	14.51*	17.69	21.9%

The above experiments were made by the Edinburgh Water Company prior to 1854 with cast iron main. In first experiment 15, the second 25, and the third 1, observations were made.

Size: diameter in inches.	Length in feet.	Head in feet lost per 100 ft.	Velocity by Observation in feet	Velocity by Riders' table per second.	Velocity by Riders' table. + means too great. − means too small
12	5200	0.0769	1.45	1.45	same
12	..	0.7307	4.35	5.07	16.55%+
12	8140	0.06757	1.42	1.352	4.78%−
12	..	0.1474	1.89	2.083	10.21%+
12		0.2211	2.21	2.612	18.19%+

The above experiments were made by James Simpson, C. E., prior to 1855, with cast iron main from Brixton to Streatham. The pipe line, 5200′ long, was about 7 years old. The others about 4 years old.

Size diameter in	Length in	Head in feet lost per	Velocity by Observation.	Velocity by Riders' tables	Velocity by Riders' table
6	1170	1.81	4.7	5.7	21.7%
6	....	4.069	7.25	8.14	12.27%
6	....	5.59	8.49	9.7	14.26%
6	....	6.24	9.26	10.32	11.44%

The above experiments were made in 1876 by Edmund Weston, C. E., of Providence, R. I., with a 6″ cast iron (tar coated) lateral (4 years old) from a 30-inch main.

Table No. 135. (Continued.)

v was calculated by using co-efficient of discharge riously determined by actual measurement of flow er different pressures. Under almost identical condis, with velocities from 3 to 10 ft. per second in a 6" , 1.5 miles long (Florida, N. Y., Water Co., Joseph B. er, C. E., President, 1892), the results obtained by the ıor agreed within from 2.5 to 8% with the amounts n in the above Table. The pipe line was new, coal coated, and care was taken to give it good alignment ng construction.

TUBERCULATION.

is the exception, not the rule, to find the interior of er pipe lines free from tuberculation. The average l tar used to-day in pipe coating varnish is inferior hat of 25 years ago, on account of the extraction of ny bi-products from it; this in part accounts for erculation in many recently laid mains, while older s in the same system are free from it. The depth tuberculation is generally from ¼" to ⅜" in cast n, and slightly greater in steel mains with same ting and length of service.

n calculating the discharge of old conduits it is not st to assume depth at less than ¾". When lines of stribution system are under consideration, 1" is not much allowance for thickness of annular ring taken by tuberculation, sediment and vegetable matter: then have

Table No. 136.

20"	reduced	in	capacity	to	that	of	clean	18"
16"	"	"	"	"	"	"	"	14"
12"	"	"	"	"	"	"	"	10"
10"	"	"	"	"	"	"	"	8"
8"	"	"	"	"	"	"	"	6"
6"	"	"	"	"	"	"	"	4"

4" reduced in area about 75% and its discharging ca-city from ½ to ⅔ eds., depending on conditions.

Mechanical appliances for scraping the interior of pe lines are used with some success. Desmond Fitz-rald, C. E., Boston, increased capacity of 48" conduit out 30% by removing 18 years growth of tubercula-n. Conduits and laterals should be flushed frequent- otherwise deposits of sediment, etc., together with erculation may interfere with proper operation of system. In direct pumping systems, unless this is ne, *more coal, other* fuel or power will be required *is necessary.*

Table No. 137.

NOTE. NO. 1—The weights of water pipe given in thi work are 10% higher than some engineers would advis but are not too high, when "water hammer" and othe causes of rupture, are properly considered. "EXTRA METAL" is always a good investment, and especially so when it is poor or not uniform in quality.

APPROXIMATE WEIGHT OF 48" CAST IRON WATER PIPE—Lengths average of 12 ft. 4 in. including bells: to lay average of 12 feet.

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per length.	in pounds per foot.	in net tons per 1000 ft.	in net tons per mile.
100	43.35	1.13	7364.	614.	307.	1620.
200	86.69	1.32	8649.	721.	360.	1906.
300	130.04	1.51	9922.	828.	414.	2185.
400	173.38	1.71	11217.	935.	467.	2468.
500	216.73	1.9	12501.	1042.	521.	2750.

APPROXIMATE WEIGHT OF 36" CAST IRON WATER PIPE; length, 12' 4"; to lay, 12'.

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per L'gth.	in pounds per foot.	in net tons per 1,000 feet.	in net tons per mile.
100	43.35	0.97	4732.	394.	197.	1041.
200	86.69	1.11	5459.	455.	227.	1201.
300	130.04	1.25	6186.	515.	258.	1362.
400	173.38	1.40	6915.	576.	288.	1521.
500	216.73	1.54	7645.	637.	318.	1682.

APPROXIMATE WEIGHT OF 30" CAST IRON WATER PIPE; length, 12' 4"; to lay, 12'.

Table No. 137. (Continued.)

APPROXIMATE WEIGHT OF 20" CAST IRON WATER PIPE (length 12' 4", to lay 12').

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per L'gth.	foot.	in net tons per 1,000 feet.	mile.
100	43.35	0.72	2067	172	86	455
200	86.69	0.80	2307	192	96	508
300	130.04	0.88	2548	212	106	561
400	173.38	0.96	2790	233	116	614
500	216.73	1.04	3030	252	126	667

APPROXIMATE WEIGHT OF 18" CAST IRON WATER PIPE (Length, 12' 4", to lay 12'.)

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per length.	foot.	in net tons per 1000 ft.	mile.
100	43.35	0.68	1688	141	70	371
200	86.69	0.75	1874	156	78	412
300	130.04	0.83	2060	172	86	453
400	173.38	0.90	2247	187	94	494
500	216.73	0.97	2435	203	101	536

APPROXIMATE WEIGHT OF 16-INCH CAST IRON WATER PIPE (Length 12' 4", to lay 12').

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per L'gth.	foot.	in net tons per 1,000 feet.	mile.
100	43.35	0.65	1423	119	59	313
200	86.69	0.71	1569	131	65	345
300	130.04	0.77	1715	143	71	377
400	173.38	0.84	1861	155	78	409
500	216.73	0.90	2007	167	84	442

APPROXIMATE WEIGHT OF 12" CAST IRON WATER PIPE (length 12' 4", to lay 12').

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per L'gth.	foot.	in net tons per 1,000 feet.	mile.
100	43.35	0.57	908	75.66	37.83	200.
200	86.69	0.62	1002	83.5	41.75	220.
300	130.04	0.66	1073	89.42	44.71	236.
400	173.38	0.71	1165	97.08	48.54	256.
500	216.73	0.76	1248	104.	52.	275.

APPROXIMATE WEIGHT OF 10" CAST IRON WATER PIPE (length 12' 4", to lay 12').

Head in feet.	Pressure in lbs. per sq. inch.	Thickness (approximate) in inches.	WEIGHT OF PIPE in pounds per length.	foot.	in net tons per 1,000 ft.	mile.
100	43.35	0.53	703	58.6	29.3	155.
200	86.69	0.57	760	63.33	31.66	167.
300	130.04	0.61	828	69.	34.5	182.
400	173.38	0.65	886	73.83	36.92	195.
500	216.73	0.69	946	78.83	39.42	208.

FOR COST of PIPE per pound at any price per ton or *gross ton, see* Table No. 133.

Table No. [illegible] (Continued.)

APPROXIMATE WEIGHT OF [illegible] CAST IRON WATER PIPE (Length [illegible], to lay [illegible]).

Head in feet.	Pressure approximate in lbs. per sq. inch.	Thickness in inches.	WEIGHT OF PIPE in pounds per length.	foot.	in net tons per 1,000 ft.	mile.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	114.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	122.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25.	132.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	141.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	150.

APPROXIMATE WEIGHT OF [illegible] CAST IRON WATER PIPE (Length [illegible], to lay [illegible]).

Head in feet.	Pressure approximate in lbs. per sq. inch.	Thickness in inches.	WEIGHT OF PIPE in pounds per length.	foot.	in net tons per 1,000 ft.	mile.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99.0

APPROXIMATE WEIGHT OF [illegible] CAST IRON PIPE (Length [illegible], to lay [illegible]).

Head in feet.	Pressure approximate in lbs. per sq. inch.	Thickness in inches.	WEIGHT OF PIPE in pounds per length.	foot.	in net tons per 1,000 ft.	mile.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.5	50.2

[redacted]

Table No. 138. (Continued.)

48" ORDINARY SPECIAL CASTINGS.

Connections with 48" conduits are generally such that
ey are made from special drawing.

36" ORDINARY SPECIAL CASTINGS.

36" Tee,	5140 lbs.	36" x 30" Tee,	4200 "
36" Sleeve,	1500 "	36" to 30" Reducer,	1730 lbs.
36" x 12" Tee,	4000 lbs.		

30" ORDINARY SPECIAL CASTINGS.

" x 30" Tee	3025 lbs.	30" x 20" Tee	2200 lbs.
" ⅛ bend (45°).......	2000 "	30" x 18" Reducer ...	1305 "
" 1-16 bend (22.5°)...	1735 "	30" x 12" Cross	2250 "
" Sleeve	965 "	30" x 12" Tee	2050 "
" Plug	370 "	30" x 10" Tee	2000 "
" to 24" Reducer....	1585 "	30" x 8" Cross	2000 "
" x 24" Tee	2640 "	30" x 6" Tee	1825 "
" x 20" Cross	2635 "		

24" ORDINARY SPECIAL CASTINGS.

4" Cross,	2200-2500 lbs.	24" to 20" Reducer,	745 lbs.
4" Tee,	1880 "	24" x 20" Cross,	2020 "
4" Elbow,	1375 "	24" x 12" Tee,	1425 "
4" 45° (⅛) bend,	1100-1425 "	24" x 8" Tee,	1375 "
4" Sleeve,	470- 710 "	24" x 6" Tee,	1325 "
4" Plug,	185 "	24" x 6" Cross,	1340 "
4" Cap,	440 "		

20" ORDINARY SPECIAL CASTINGS.

20" Cross	1750-1790 lbs.	20" x 12" Cross.	1190-1370 lbs.
20" Tee	1320-1375 "	20" x 12" Tee....	985-1090 "
20" ¼ bend (90°).........	900 "	20" to 12" R'd'cer	450- 540 "
20" ⅛ bend (45°).........	740 "	20" x 10" Cross.	1070-1225 "
20" Y	1300-1650 "	20" x 10" Tee....	910-1025 "
20" Sleeve	350- 500 "	20" x 8" Cross...	960-1080 "
20" Plug	150- 175 "	20" x 8" Tee.....	870- 920 "
20" Cap	275- 550 "	20" to 8" Reducer.....	300 "
20" x 18" Cross	1615 "	20" x 6" Cross ..	870-1000 "
20" x 18" Tee	1240 "	20" x 6" Tee	780- 875 "
20" to 18" Reducer	570 "	20" x 6" Blow-off br.	745 "
20" x 16" Cross	1485 "	20" x 6" Hydrant br.	770 "
20" x 16" Tee	1160 "	20" x 4" Cross	775 "
20" to 16" Reducer	530- 700 "	20" x 4" Tee	720 "

18" ORDINARY SPECIAL CASTINGS.

18" Cross..............	1465 lbs.	18" x 16" Tee..........	1030 lbs.
18" Tee..................	1100 "	18" x 12" Cross........	1060 "
18" Y......................	1090 "	18" x 12" Tee..........	860 "
18" 90° (¼) bend.......	760 "	18" x 10" Cross........	945 "
18" 45° (⅛) bend.......	720 "	18" x 10" Tee..........	790 "
18" Sleeve..............	315 "	18" x 8" Cross........	845 "
18" Cap..................	240 "	18" x 8" Tee..........	730 "
18" x 16" Cross.........	1350 "	18" x 6" Cross........	760 "
18" to 12" Reducer....	395 "	18" x 6" Tee..........	675 "
18" to 16" Reducer....	475 "	18" x 4" Cross........	670 "
18" to 10" Reducer....	360 "	18" x 4" Tee..........	620 "

For COST for FREIGHT and CARTAGE, see Table *No. 133.*

Table No. 139.

Table showing the average cost of laying Water Pipes, from experience in the construction of thirty water works, by WILLIAM B. RIDER, C. E., late of Conn. State Board of Engineers, Member of American Water Works Association, &c., &c., South Norwalk, Conn.

Size	Pipe (200 Feet Head)			Lead.			Hemp Packing.			Excavation.	Trenching and Re-filling.	Pipe laying.	Cartage, Two Miles.		Superintendence and Minor Incidentals.	Pipe Laying, Complete.		Approximate Figures.
	Weight per length including bell, (in lbs. 12 feet.)	Weight in lbs. per lineal foot.	Cost per lineal foot at $30 per gross ton.	Pounds per joint.	Pounds per lineal foot.	Cost per lineal ft. at 6 cts. per lb. delivered on work.	Pounds per joint.	Pounds per lineal foot.	Cost in cts. per lineal ft. at 7 cts. per lb. delivered on work.	Cubic feet per lineal foot, (pipe covered 4 feet.)	Cost per lineal foot.	Cost per lineal foot.	Number of Pipe on truck.	Cost per lineal foot.	Cost per lineal foot.	Cost per lineal ft. not including cost of pipe.	Cost per lineal ft. including cost of pipe.	Easily Remembered.
[illegible]	240	20	$0.267	6	0.5	$.03	0.2	0.0166	0.117	8	$.12	$.025	14	$.0086	$.018	$.201	$ .47	$ .45
[illegible]	360	30	.4017	9	.75	.045	0.4	0.033	0.233	10	.15	.0275	10	.0084	.020	.2525	.66	.65
[illegible]	540	45	.6026	12	1	.06	0.6	0.05	0.35	12	.18	.04	6	.0139	.02	.30	.90	.90
[illegible]	720	60	.8035	15	1.25	.075	0.8	0.066	0.466	13.5	.22	.05	5	.0167	.0225	.416	1.22	1.20
[illegible]	960	80	1.0712	18	1.5	.09	0.9	.075	0.525	14	.25	.06	4	.0234	.0449	.4885	1.555	1.55
[illegible]	1500	125	1.6741	24	2	.12	1.0	.0833	0.583	17	.315	.10	3	.03125	.057	.63	2.30	2.30
[illegible]	1776	148	1.9821	27	2.25	.135	1.25	.104	0.73	18	.38	.12	2	.0468	.064	.71	2.69	2.70
[illegible]	2100	175	2.3437	32	2.66	.16	1.5	.125	0.875	21	.39	.15	2	.0468	.075	.83	3.173	3.20
[illegible]	2784	232	3.1071	36	3	.18	1.75	.1458	1.02	27	.60	.20	1	.09375	.096	1.09	4.19	4.20

References.

The above table is based on data obtained by the author in constructing Water Works at the following places:

Bethel, Conn.	Mamaroneck, N. Y.
Belle Haven, Conn.	Port Chester, N. Y.
Danbury, Conn.	Prattsville, N. Y.
East Norwalk, Conn.	Oneonta, N. Y.
East Port Chester, Ct.	Rye, N. Y.
Greenwich, Conn.	Sandy Hill, N. Y.
Kent, Conn.	Stamford, N. Y.
Norwalk, Conn.	Sidney, N. Y.
South Norwalk, Conn.	Walton, N. Y.
Thomaston, Conn.	Waterville, N. Y. (public)
Torrington, Conn.	Waterville, N. Y. (private)
Deposit, N. Y.	Orange, N. J.
Haverstraw, N. Y.	&c., &c., &c.
Hornellsville, N. Y.	
Harrison, N. Y.	

48 Plants to 1901 by W. B. & J. B. Rider.

Weight of Pipes.

The weights given are an average weight, and are what one may expect when ordering pipe of reputable makers for 200 feet head.

Lead and Hemp Packing.

The amount of lead given for 4, 6, 8, 10 and 12 inch pipes includes setting of all necessary valves, specials and hydrants. The amount given for the larger sizes includes setting an occasional gate or special.

In estimating cost for lead, hemp-packing, pipe-laying, cartage, etc., it is assumed that each pipe will lay 12 ft. In practice it varies from 11.75 ft. to 12.45 ft.

Trenching.

The cost for trenching includes one man constantly pumping with an ordinary diaphragm pump. The cost shown is the average cost of digging in the places hereto annexed. It is too small for very hard digging and too large for easy digging.

Superintendence.

This does not include cost for engineering, but does for Foreman, Time-keeper, etc.; also sharpening and mending tools.

Pipe-Laying.

One good calker is better than ten poor ones. Two good calkers are most economical.

A good "lead boy" will save, in maintaining the fire at the right temperature, more than his wages.

Two tripod derricks with 3 in. x 4 in. legs, with differential pulley-blocks, are advantageous in laying 10, 12 and 16 in. pipe. Heavier derricks and differential blocks have been used with satisfaction in laying larger sizes.

Cartage.

The cost for cartage is not based on the weight carried, but on the number of pipe that can be conveniently carried on an ordinary truck. The average price paid for man and team has been $4.00 per day. If more than four trips are made (16 to 20 miles) over an ordinary road each day, experience proves that what is gained in the decreased cost per lineal foot for cartage is more than balanced by the depreciation in the value of the team. When distance is from 6 to 8 miles, team will seldom make over 2 trips a day.

Rock Excavation.

The table does not include rock excavation. Its cost depends, 1st, upon the position of the layers of stratification, 2d, upon the tools and explosives used, 3d, upon the measurement allowed by the Engineer. A fair allowance for rock measurement is as follows: All boulders measuring ¼ of a cu. yd. and all stone, that, in the opinion of the Engineer require blasting, shall be measured as rock. In rock cuts less than 8 ft. deep, if the width at the bottom is taken as one foot greater than the external diameter of the body of the pipe, and width at the top, is assumed to be the bottom width plus 75-100 of the depth of the trench, an Engineer will seldom allow the Contractor more rock than he has removed.

The average cost of rock excavation (trench work) has been as follows: Granite or Gneis, $4.50 per cu. yd., Limestone, $4.00 per cu. yd., Volcanic Tuff, $3.00 per cu. yd., Sand Stone, $2.50 per cu. yd.

On recent work at Port Chester, N. Y., under the supervision of Joseph B. Rider, C. E., the cost for explosives in excavating 7000 cu. yds. of rock in trenches, (average depth 7 ft.) was nearly 50 cents per cubic yard.

Average cost for labor, lumber, fuel, etc., chargeable to pipe laying has been $15.75 per day, and average days work to nearest full length, for the gang has been,

53 lengths of 4″ or 636′		13 lengths of 16″ " 156′	
48 " " 6″ " 576′		11 " " 18″ " 132′	
33 " " 8″ " 396′		9 " " 20″ " 108′	
22 " " 10″ " 264′		7 " " 24″ " 84′	
17 " " 12″ " 204′		6 " " 30″ " 72′	

Electric currents escape from the return conductors (rails and wire)as laid on or near the surface of streets and highways by most traction companies. The numerous gas and water mains, cables, etc., beneath the streets, form separate, generally, net works of un-insulated conductors in contact with the earth and any current escaping from a conductor because it is too small or offers too great resistance and flowing from it to the earth will be at least partly carried by them. At the surface of contact between the pipe and the earth, where the current escaping from the rail or other conductor enters the pipe, no harm is done, but at every point where the current leaves the pipe, natural corrosion will be accelerated by an amount proportional to the magnitude of the current leaving the pipe line.

The activity of the distruction will depend somewhat on the moisture in the soil, but in no case is it absent.

Because of the metallic joints, certain old gas mains offer somewhat less resistance to flow of current than the common lead or cement joint. The hemp packing of the lead joint is a barrier and the current leaves the pipe line near the joints, passing around and returning just beyond them forming arcs as in the electric light. At each joint, at "dead ends," at and near power stations and at other points where the current has followed the pipe line until meeting considerable resistance, it leaves the line, electrolytic action taking place, damaging if not destroying the pipe.

Fig. 33 is selected from a collection of nearly one hundred similar photographs in the author's possession as showing plainly the "graphite holes" in a water pipe line caused by escape of electric current. It will be noticed that the major portion of them are toward one end of the pipe, showing plainly that the current passed around a joint as above mentioned.

The pipe shown was laid new July 21, 1899, and removed August 8, 1900, at Reading, Pa. (Emil L. Nuebling, C. E., Supt. of Water Works). Voltmet[er] readings as high as 42 volts were recorded in th[e] "Hydrant and Rail Survey," and in vicinity of p[ipe] shown by Fig. 33 from 4 to 25 volts.

Fig. 33.—Showing effect of Electrolysis on cast iron water main in one year and eighteen days. (See text.)

[illegible]

[illegible] days. [illegible]

[illegible] many plac[illegible]

[illegible] Milwaukee, [illegible]

[illegible] Me. [illegible] many [illegible]

[illegible] companies [illegible]

[illegible]

ɔn of the year, or where bonding has deteriorated ency. Nothing is so destructive of good bond- 'wheel hammer"; good track alignment, heavy best foundation, and ROUND wheels will reduce a minimum.

survey should locate poorly bonded sections of nd other points of escape from track, cable con- pipe line. Repairs should be made at once, and nt still escapes. return track feeders and cross between rails should be properly provided.

ɔns of dollars are invested in pipe lines, etc., s but equitable that damage done to them by n companies should be promptly made good. n franchises should not be granted unless ample given to repair forthwith damage attributable pe of electric current. When such bond is re- the double trolley system will probably be l. It is the only method so far in practical use solutely insures proper protection to private and metallic structures. In the absence of such a , the best that can be done is to insist on electric ction that will reduce escape to a minimum. terest on the extra cost of such construction, or ne double trolley system, is less than the extra fuel, etc., necessary to operate an electric road light rails, poor bonding, etc. The average cost to operate the poorly equipped road being one-third greater per car mile.

RELATIVE TO TABLE NO. 140.

discharge of a compound conduit can be compu- Westons or other complicated formula. Its use s from 10 minutes to an hour or more of time, de- g on the number of sections to conduit and es from it, while to insure accuracy of computa- ne must be free of "rust." By use of Table No. aking one less multiplication than there are sec- f the line, a glance at the proper preceding table charge, the discharge of the compound line is

The example given on page 237 explains the ation of the table to the ordinary problem of prac- It is self-evident that the proper use of the table ver cases of two or more parallel compound lines rging into one or more laterals, which in turn dis- at *different locations* in a pipe system.

[redacted]

Table No. 140.

[redacted] Conduit Table

[redacted] Pipe line, consuming the same amount of head as one linear [redacted], when discharging the same quantity of water.

[redacted] by Joseph B. Rider, C. E.)

	16"	18"	20"	24"	30"	36"	48"
[redacted]	823.	1470.	2450.	5900.	17400.	42000.	169000.
	116.4	2055.	342.	823.	2450.	5900.	23900.
	28.8	51.	85.	205.	600.	1470.	5900.
	9.7	17.2	28.8	69.6	205.	500.	1987.
	4.03	7.1	11.9	28.8	85.	205.	823.
	1.	1.77	2.94	7.1	21.	51	205.
	0.565	1.	1.67	4.03	11.9	28.8	116.4
	0.34	0.6	1.	2.415	7.1	17.2	69.6
	0.14	0.248	0.413	1.	2.94	7.1	28.8
	0.0475	0.084	0.14	0.34	1.	2.415	9.7
	0.0196	0.035	0.058	0.14	0.413	1.	4.03
	0.00487	0.0086	0.0143	0.035	0.035	0.248	1.

[redacted] page and example on following page.

EXAMPLE, showing application of Table No. 140.

REQUIRED, rate of consumption of a city, supplied by gravity from a reservoir, having given the following data.

Gates in laterals closed so that the supply is passing through the following pipe lines in succession, all below hydraulic grade. *See page 240.

20" to 16" reducer, (neglected in calculation.)

15000' of 16" from reservoir to 12" reducer.

5000' of 12" from end of 16" to 10" reducer.

3000' of 10" from end of 12" to 8" reducer.

1000' of 8" from end of 10" to opposite hydrant, where pressure of 70 lbs. is noted during the test; the nozzle of hydrant being 225' lower than water in reservoir, and there being no serious obstruction at Intake Chamber, and combined line free from tuberculation, air locks, etc.

By the table we can reduce each portion of the line to its equivalent length of any other size, but, as a rule, it is best and easier to reduce all to the largest size of pipe making up the combination line. Reducing all to 16" line, we have from the table:

15000' of 16" =....................	15000' of 16"
5000' of 12" = 5000 x 4.03 =........	20150' of 16"
3000' of 10" = 3000 x 9.7 =........	29100' of 15"
1000' of 8" = 1000 x 28.8 =..	28800' of 16"

Head lost in compound conduit same as in 93050' of 16'

From Table No. 141 we have 70 lbs. pressure = 162' head nearly. Subtract this from the total head (static) 225 we have 63' as the friction head lost in discharging the water through the compound conduit. Our equivalent 16" line will be 93050' long and loosing 63' head or 0.0677' per 100'.

Looking at Table No. 126 we find this loss of head in second column, between 1.6 and 1.7 ft. velocity per second. To allow for contingencies, we take the next lowest or 1.6 ft. per second, and find the discharge given opposite to be 2.233 cubic ft. second, 1003 gal. minute, 60159 gal. hour, 1,443,818 gal. day, or 111.69 California miners' inches.

If the several sections of the pipe line are not free from air, tuberculation or other obstruction; allow proper safety factor, based on the actual experiments, *data relative to tuberculation*, etc., before given.

Table No. 141.

TABLE OF EQUIVALENTS.

HEAD IN FEET AND PRESSURE OF WATER IN P
PER SQUARE INCH.

Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.
1	0.43	65	28.15	129	55.88	193	83.60	257
2	0.86	66	28.58	130	56.31	194	84.03	258
3	1.30	67	29.02	131	56.74	195	84.47	259
4	1.73	68	29.45	132	57.18	196	84.90	260
5	2.16	69	29.88	133	57.61	197	85.33	261
6	2.59	70	30.32	134	58.04	198	85.76	262
7	3.03	71	30.75	135	58.48	199	86.20	263
8	3.46	72	31.18	136	58.91	200	86.63	264
9	3.89	73	31.62	137	59.34	201	87.07	265
10	4.33	74	32.05	138	59.77	202	87.50	266
11	4.76	75	32.48	139	60.21	203	87.93	267
12	5.20	76	32.92	140	60.64	204	88.36	268
13	5.63	77	33.35	141	61.07	205	88.80	269
14	6.06	78	33.78	142	61.51	206	89.23	270
15	6.49	79	34.21	143	61.94	207	89.66	271
16	6.93	80	34.65	144	62.37	208	90.10	272
17	7.36	81	35.08	145	62.81	209	90.53	273
18	7.79	82	35.52	146	63.24	210	90.96	274
19	8.22	83	35.95	147	63.67	211	91.39	275
20	8.66	84	36.39	148	64.10	212	91.83	276
21	9.09	85	36.82	149	64.54	213	92.26	277
22	9.53	86	37.25	150	64.97	214	92.69	278
23	9.96	87	37.68	151	65.40	215	93.13	279
24	10.39	88	38.12	152	65.84	216	93.56	280
25	10.82	89	38.55	153	66.27	217	93.99	281
26	11.26	90	38.98	154	66.70	218	94.43	282
27	11.69	91	39.42	155	67.14	219	94.86	283
28	12.12	92	39.85	156	67.57	220	95.30	284
29	12.55	93	40.28	157	68.00	221	95.73	285
30	12.99	94	40.72	158	68.43	222	96.16	286
31	13.42	95	41.15	159	68.87	223	96.60	287
32	13.86	96	41.58	160	69.31	224	97.03	288
33	14.29	97	42.01	161	69.74	225	97.46	289
34	14.72	98	42.45	162	70.17	226	97.90	290
35	15.16	99	42.88	163	70.61	227	98.33	291
36	15.59	100	43.31	164	71.04	228	98.76	292
37	16.02	101	43.75	165	71.47	229	99.20	293
38	16.45	102	44.18	166	71.91	230	99.63	294
39	16.89	103	44.61	167	72.34	231	100.06	295
40	17.32	104	45.05	168	72.77	232	100.49	296
41	17.75	105	45.48	169	73.20	233	100.93	297
42	18.19	106	45.91	170	73.64	234	101.36	298
43	18.62	107	46.34	171	74.07	235	101.79	299
44	19.05	108	46.78	172	74.50	236	102.23	300
45	19.49	109	47.21	173	74.94	237	102.66	310
46	19.92	110	47.64	174	75.37	238	103.09	320
47	20.35	111	48.08	175	75.80	239	103.53	330
48	20.79	112	48.51	176	76.23	240	103.96	340
49	21.22	113	48.94	177	76.67	241	104.39	350
50	21.65	114	49.38	178	77.10	242	104.83	360
51	22.09	115	49.81	179	77.53	243	105.26	370
52	22.52	116	50.24	180	77.97	244	105.69	380
53	22.95	117	50.68	181	78.40	245	106.13	390
54	23.39	118	51.11	182	78.84	246	106.56	400
55	23.82	119	51.54	183	79.27	247	106.99	500
56	24.26	120	51.98	184	79.70	248	107.43	600
57	24.69	121	52.41	185	80.14	249	107.86	700
58	25.12	122	52.84	186	80.57	250	108.29	800
59	25.55	123	53.28	187	81.00	251	108.73	900
60	25.99	124	53.71	188	81.43	252	109.16	1000
61	26.42	125	54.15	189	81.87	253	109.59	
62	26.85	126	54.58	190	82.30	254	110.03	
63	27.29	127	55.01	191	82.73	255	110.46	
64	27.72	128	55.44	192	83.17	256	110.89	

Table No. 142.

…scharging Capacity of Service Pipes in Gallons per Minute.

…en length of pipe in feet equals …ead in feet ×	Pressure in lbs ×	3	2½	2	1½	1¼	1	¾	⅝	½
		Diameter of service pipe in inches								
10.0	23.07	175	110	63	31	19	11.	5.4	3.5	2.0
9.0	20.76	184	116	67	32	21	11.8	5.7	3.6	2.1
8.0	18.45	195	124	71	34	22	12.5	6.1	3.9	2.2
7.0	16.15	208	132	76	37	23	13.4	6.5	4.1	2.4
6.0	13.84	225	143	82	40	25	14.4	7.0	4.4	2.6
5.0	11.53	247	156	89	44	28	15.8	7.7	4.8	2.8
4.0	9.22	276	175	100	49	31	17.7	8.6	5.5	3.1
3.0	6.92	318	202	115	56	56	20.4	9.9	6.3	3.6
2.0	4.61	390	247	141	69	44	25.	12.2	7.7	4.4
1.33	3.07	477	302	173	84	56	31.	15.	9.5	5.4
1.0	2.31	556	349	200	97	62	35.	17.	10.9	6.3
0.8	1.85	616	390	224	109	69	40.	19.	12.2	7.0
0.66	1.54	675	428	249	119	76	43.	21.	13.4	7.7
0.57	1.31	729	462	264	129	82	47.	23.	14.4	8.3
0.50	1.15	780	499	283	138	87	50.	24.	15.4	8.8
0.33	0.77	956	605	346	169	107	61.	30.	18.9	10.8
0.25	0.58	1103	699	400	195	123	71.	34.	21.8	12.5
0.20	0.46	1244	781	447	218	138	79.	39.	24.4	14.
0.166	0.38	1351	855	488	230	151	87.	42.	26.5	15.3
0.143	0.33	1460	924	529	258	163	94.	46.	28.9	16.5
0.125	0.29	1560	988	566	275	175	100.	49.	30.1	17.7
0.111	0.26	1651	1048	600	292	185	106.	52.	32.7	18.7
0.1	0.23	1745	1104	632	308	195	112.	54.	34.5	19.8

Example: Given—1½″ service pipe, 50′ long; Required discharge under 250′ head.

Here the length 50 ÷ 250 = 0.2 × the head. Opposite 0.2 in the first column, and under 1½″ pipe, find 218 gallons per minute, the discharge required. If the quotient of length ÷ by head is not given exactly in first column, it is well to take the next lowest number in order to provide for angles or other obstruction to flow.

Table No. 143.

Table for Equalizing Pipes.

Size of service pipe in inches	2	3	4	5	6	7	8	9	10	11	12	13	14
	Number of branches												
1	.758	.644	.574	.525	.488	.459	.435	.415	.398	.383	.370	.358	.348
1¼	.985	.838	.747	.683	.635	.597	.556	.540	.518	.498	.482	.466	.452
1½	1.14	.967	.861	.788	.733	.689	.653	.623	.597	.575	.555	.538	.522
2	1.52	1.29	1.15	1.05	.977	.918	.870	.830	.796	.766	.740	.717	.696
2½	1.89	1.61	1.44	1.31	1.22	1.15	1.09	1.09	.995	.958	.925	.896	.870
3	2.27	1.92	1.72	1.58	1.47	1.38	1.31	1.25	1.19	1.15	1.11	1.08	1.04

See note next page.

... discharge end of a p
... is laid on a les
... lower end wil
... grade The d
... be greater than th
... supply to the high p
... hill the more rapi
... likewise with water r
... therefore in orde
... much water as can
... and from the high p
... the source of sup
... diameter than pipe fr
... it will be
... rather than lay
...
... grade. Draw ga
...
... when fi

STEAM AND FUEL NOTES.

...

It is quite time that certain people realized the fact that 100 per cent. is all there is in anything and that some purchasers and engineers know it. While without question certain auxiliary apparatus is necessary and beneficial and that some properly designed modern steam plants are very economical in operation, others are so complicated with "steam savers" etc., that they are far less efficient than many old fashioned plants. The engineer's unbiased judgment must be used in lesigning if appurtenances intended to assist the oiler, engine or pump are not to be an actual load for hem.

HEAT:—Is measured by the change in temperature it roduces in any substance.

In the U. S., the B. T. U. (British Thermal Unit) s the unit of measure and is the quantity of heat necessary to raise the temperature of one commercial ound of water from 62° to 63° Fahr. In France the eat unit is called the Calorie and is the quantity of heat ecessary to raise one kilogram of water 1° centigrade t or about a temperature of 4° centigrade.

1 B. T. U. = 0.252 Calorie.

1 Calorie = 3.968 B. T. U.

THERMOMETERS.—In Russia, Sweden, Turkey, Egypt nd certain other countries, the Reaumur scale is used. The scales (thermometers) compare as follows:

	FAHRENHEIT.	CENTIGRADE.	REAUMUR.
Melting point of ice,	32.°	0.°	0.
Boiling point of water (a)	212.°	100.°	80.

(a) Boiling point of water at atmospheric pressure of 14.7 pounds per sq. in.

At 7.7 lbs. pressure per sq. in. water boils at 160° Fahr.
" 14.7 " " " " " " " 212° "
" 24.7 " " " " " " " 239 "
" 114.7 " " " " " " " 338° "

1 deg. *Fahr.	$= \frac{5}{9}$ deg. †Centi.	$= \frac{4}{9}$ deg. ‡Rea.
1 deg. Centi.	$= \frac{9}{5}$ deg. Fahr.	$= \frac{4}{5}$ deg. Rea.
1 deg. Rea.	$= \frac{9}{4}$ deg. Fahr.	$= \frac{5}{4}$ deg. Centi.
Temp. Fahr.	$= \frac{9}{5} \times$ temp. C. + 32 deg.	$= \frac{9}{4}$ temp. R + 32°.
Temp. Centi.	$= \frac{5}{9}$ (temp. F.—32 deg.)	$= \frac{5}{4}$ temp. R.
Temp. Rea.	$= \frac{4}{5}$ temp. Centi.	$= \frac{4}{9}$ temp. (F.—32°.)

* Means Fahrenheit.
† Means *Centigrade.*
‡ *Means Reaumur.*

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Cent.	Fahr.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	76	168.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77	170.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	78	172.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79	174.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	176.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	177.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82	179.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83	181.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84	183.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85	185.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	86	186.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87	188.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88	190.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89	192.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	90	194.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91	195.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92	197.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93	199.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94	201.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	95	203.0

Table No. 145.

DUCTION TABLE. FRENCH TO U.S. AND BRITISH EQUIVALENTS.

:h Mechanical Equivalent / :ilogram-Meters	...3075 Foot-Pounds.
Kilogram-Meters	1 Joule = 778 Foot-Pounds.
:alorie per sq. meter ...	0.369 B. T. U. per sq. ft.
" " "	1. " " "
" " Kilogram	1.8 " " lb.
" " "	1- " " "

Table No. 146.

TABLE OF EQUIVALENTS.

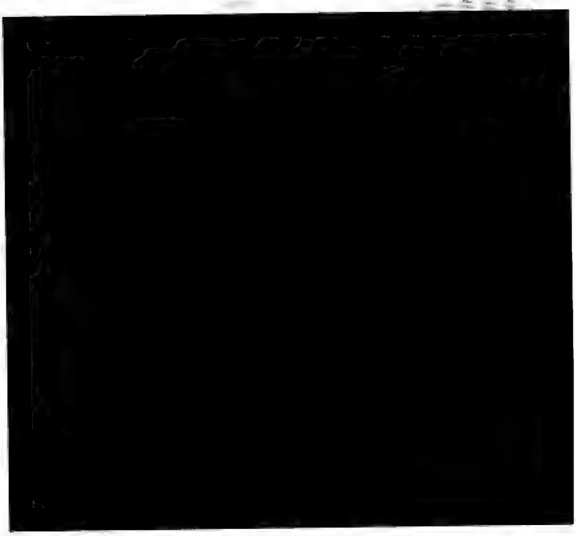
T. T. (t Unit.)	Foot-Pounds.	Watts.*	Horse-Power.
.	778.	17.59	.0236
.001285	1.	.0226	.0000303
.0568	44.23	1.	.00136
:.41	33000.	746.	1.

OMBUSTION.—Is a chemical combination of the combtible parts of a fuel, chiefly carbon and hydrogen 1 the oxygen of the air.

ure Air is a mechanical, not chemical, mixture of
)arts by weight of oxygen and
" " " " nitrogen or
)arts by volume of oxygen and
" " " " nitrogen.

Vith barometer at 30″ and temp. of 60 Fahr. one ınd of air occupies a space of 13.06 cu. ft. Under ıstant pressure it and other elastic fluids expand ıen heated and the volume varies uniformly with the nperature. Other conditions being the same, the ılumes of equal weights of elastic fluids are proırtional to their specific gravities. At "absolute zero")2° below the freezing point of water on the Fahr., ale, or 460° below zero of the same scale) a volume of r occupying 460 cu. ft. at zero would occupy but 1 cu. ft. ndęr same pressure at absolute zero; therefore a volme of air is proportional to its absolute temperature r temp. Fahr. scale + 460 degrees. Its volume will lso vary inversely as the pressure.

* Watt=Electric Unit=1 Amphere × 1 Volt.
746 Watts=1 Horse Power.



To admit double the quanity of air, reduces this amount to 81 per cent. +. It is evident therefore that the maximum value of a fuel is obtained when the excess of air admitted is a minimum.

Any arrangement of boiler and appurtenances that tends to reduce temperature of gases escaping to chimney to a minimum or to as near the temperature of the boiler as possible is beneficial, provided the heat units are absorbed directly by the water in or to be used in the boiler.

In the following formulae which will be found convenient, letter C = Carbon in per cent. H = Hydrogen in per cent. O = Oxygen in per cent. of weight of fuel.

Heats Units due to burning one lb of combustible	=	145C+620 [H—(O÷8)] which becomes when the Oxygen is not determined, 145 C. + 620 H.
Amount of air at 62° Fahr. required to burn 1 lb. fuel.	=	[(3 H. + C.) — 0.4 O] 152.
Weight of product of combustion 1 lb. of fuel	=	0.358 H. + 0.126 C.
Volmue of product of combustion of 1 lb. of fuel at, 60° Fahr.)	=	5.52 H. + 1.52 C . . . . . . (a)
Volume at any at any other temperature	=	$\frac{\text{Other temperature} + 461}{523}$ (a)
Evaporative power at 212° Fahr. of 1 lb. of fuel	=	(4.28 H. + C.) 0.15.

BITUMINOUS COAL.—Broken loose weighs 47 to 52 pounds per cu. ft. Moderately packed 51 to 56 pounds. Heaped bushel weighs 70 to 78 pounds. Ton occupies space of 43 to 48 cu. ft.

In Penn. 76 pounds of bituminous coal make a bushel.

In Indiana 70 pounds of bituminous coal make a bushel.

In Illinois, Kentucky and Missouri, 80 pounds Bituminous coal makes a bushel.

ANTHRACITE COAL. Market sizes, loose weighs 52 to 56 pounds per cu. ft. Moderately packed, 56 to 60 pounds. Heaped bushel, loose, 77 to 83 pounds. Gross Ton occupies space of 40 to 43 cu. ft.

When exposed to the air and weather, coal rapidly deteriorates in value as a fuel. It undergoes slow combustion, generating heat frequently to a dangerous extent. A year's exposure under favorable conditions will produce a loss of 25 to 50 per cent. in heating value.

COKE DRY.—Weighs 23 to 32 pounds per cu. ft. or 35 to 42 pounds per heaped bushel. One ton of coal produces about 40 bushels of coke.

Table No. 148.

HEATING AND EVAPORATING POWER OF COAL.

COAL FROM	Heat Units (B.T.U.) per lb.	Theoretical evaporation in lbs. of water from & at 212° F.	Heat Units (B.T.U.) per lb.	Theoretical evaporation in lbs. of water from & at 212° F.
	Of Average poor quality.		Of average best quality.	
Arkansas	[illegible]	12.16	12687	12.9
[illegible]	9450	9.78	11700	12.12
Indiana [illegible]			10407	10.77
Indian Territory	11000	11.47	12800	13.25
Iowa	8702	9.02	11370	11.77
Kentucky			13345	13.81
Maryland			13700	14.18
Missouri			12950	13.42
New Mexico	9414	9.75	11750	12.17
[illegible]			13300	13.78
Pennsylvania [illegible]	11600	12.01	14000	14.49
[illegible]			13104	13.46
[illegible]			13035	13.49
[illegible]			11739	12.15
[illegible]			13563	14.04
[illegible]	12600	13.04	13480	13.95
Tennessee [illegible]	12217	12.65	12600	13.04
Tennessee			13167	13.63
Texas [illegible]			11803	12.22
Virginia [illegible]	9450	9.78	13363	13.83
Washington			12316	12.75
West Virginia, New River,			13374	13.84
Best.	12800	13.25	14200	14.17

Table No. 148. (Continued.)

AVERAGE ANALYSIS.

Kind of Coal.	Fixed Carbon. per cent.	Sulphur per cent.	Ash per cent.	Moisture per cent.	Volatile Matter per cent.
Anthracite,	78.40	0.0	13.2	2.	6.4
Bituminous,	60.1	0.84	6.4	1.7	31.8
s, Good,	54.6	1.78	8 3	6.4	30.6
Average,	43.8	3.35	12.8	9.9	33.4
Virginia,	77.6	0.26	2.9	0.85	18.4

ood.—When "dry" as the term is generally used contains about 15 to 30 per cent. moisture. For ng purposes one pound of either of these woods is etically = to a pound of any other wood in the ving table.

Table No. 149.

COMPARATIVE VALUE OF WOOD AND COAL.

Chord of erage	Weighs		Pounds of Average Coal.		
ech,	3250 lbs.	=	1450	as a	fuel.
ack Oak,	" "	=	"	"	"
iestnut,	2350 "	=	1050	"	"
m,	" "	=	"	"	"
ickory,	4500 "	=	2000	"	"
aple, hard,	" "	=	"	"	"
ne,	2000 "	=	900	"	"
opular,	2350 "	=	1050	"	"
ed Oak,	3250 "	=	1450	"	"
hite Oak,	3850 "	=	1700	"	"

deep fire must be carried under boiler with wood

etroleum.—Hydrocarbon liquid, specific gravity ±. Heating power, 20,400± B. T. U. per pound of oleum. Evaporative power 21± pounds water from at 212° Fahr. Crude petroleum weighs about 55 nds per cu. ft. or 7.35 lbs. per gallon. Naptha ghs about 53 pounds per cu. ft. or 7.09 lbs. per on. Petroleum Oils, are obtained from petroleum distillation and are compounds of carbon and rogen varying from $C_{10}H_{24}$ to $C_{32}H_{64}$.

ecific Gravity 0.63 to 0.79.

eating power, 26,000 to 28,000 ± B.T.U. per pound il.

vaporative power, 28± to 29± pounds water from at 212° *Fahr.*

[illegible] properly suppor[illegible]

[illegible] name will be [illegible]

[illegible] power. 20 po[illegible]

[illegible] power. 12 [illegible]

[illegible]

[illegible] heating value [illegible]

[illegible]

[illegible] heating value about [illegible]

[illegible] Tons of coal [illegible]

[illegible]

[illegible] 550.

[illegible] (L., AN[illegible]

[illegible] Equ[illegible] per[illegible]

Table No. 151.

Wrought Iron Welded Pipe.

:nsions, Weights, Areas, etc., of Standard Sizes for Water, Steam, Gas, Oil, etc.

Outside Diameter	External Circumference	Length of Pipe per sq. foot of outside surface	Internal Area	External Area	Length of Pipe containing one cubic ft. of surface	Weight per foot of Length	No. of Threads per inch of Screw	Contents in Gallons per foot	Weight of Water per foot of Length
Inches.	Inches.	Feet.	Inches.	Inches.	Feet.	Lbs.			Lbs.
.40	1.272	9.44	.057	.129	2500.	.24	27	.0006	.005
.54	1.696	7.075	.104	.229	1385.	.42	18	.0026	.021
.67	2.121	5.657	.191	.358	751.5	.56	18	.0057	.047
.84	2.652	4.502	.304	.554	472.4	.84	14	.0102	.085
1.05	3.299	3.637	.533	.866	270	1.12	14	.0230	.190
1.31	4.134	2.903	.861	1.357	166.9	1.67	11½	.0408	.349
1.66	5.215	2.301	1.496	2.164	96.25	2.25	11½	.0638	.527
1.9	5.969	2.01	2.038	2.835	70.66	2.69	11½	.0918	.760
2.37	7.461	1.611	3.355	4.430	42.91	3.66	11½	.1535	1.356
2.87	9.032	1.328	4.783	6.491	30.11	5.77	8	.2500	2.116
3.5	10.996	1.091	7.388	9.621	19.49	7.54	8	.3878	3.049
4.	12.566	.955	9.887	12.566	14.56	9.05	8	.4948	4.155
4.5	14.137	.849	12.730	15.904	11.31	10.72	8	.5518	5.405
5.	15.708	.765	15.939	19.635	9.03	12.49	8	.6853	6.851
5.56	17.475	.629	19.990	24.299	7.20	14.56	8	1.080	8.500
6.62	20.813	.577	28.889	34.471	4.98	18.76	8	1.499	12.312
7.62	23.954	.500	38.737	45.663	3.72	23.41	8	1.998	16.662
8.62	27.096	.444	50.039	58.426	2.88	28.34	8	2.611	21.750
9.68	30.433	.394	63.633	73.715	2.26	34.67	8	3.300	27.500
10.75	33.772	.355	78.855	90.792	1.80	40.64	8	4.051	34.000

ıer of threads—1 to 32 on each side. 1¼ in. and below gen- ›roved to 300 lbs. per sq. in. hydraulic pressure. 1½ in· ·ger generally, proved to 500 lbs. per sq. in. hydraulic ·e. 11", 45 lbs., 8 threads; 12", 49 lbs., 8 threads are also The above standards and any special size can be obtained galvanized or asphalted.

.ss Tubing is generally 27 threads per inch.

Table No. 152.

Wrought Iron Pipe Measurements.

Taper ¾-inch to one foot.

·ize of Pipe.	Size of Tapping.	Outside of Thread.	Length of Thread.	Number of Threads.
$\frac{1}{8}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{9}{32}$	27
$\frac{1}{4}$	$\frac{29}{64}$	$\frac{33}{64}$	$\frac{3}{8}$	18
$\frac{3}{8}$	$\frac{19}{32}$	$\frac{21}{32}$	$\frac{7}{16}$	18
$\frac{1}{2}$	$\frac{23}{32}$	$\frac{27}{32}$	$\frac{1}{2}$	14
$\frac{3}{4}$	$\frac{15}{16}$	$1\frac{1}{16}$	$\frac{9}{16}$	14
1	$1\frac{3}{16}$	$1\frac{11}{32}$	$\frac{5}{8}$	$11\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{15}{32}$	$1\frac{5}{8}$	$\frac{11}{16}$	$11\frac{1}{2}$
$1\frac{1}{2}$	$1\frac{23}{32}$	$1\frac{15}{16}$	$\frac{13}{16}$	$11\frac{1}{2}$
2	$2\frac{3}{16}$	$2\frac{3}{8}$	$\frac{7}{8}$	$11\frac{1}{2}$
$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{7}{8}$	1	8
3	$3\frac{1}{4}$	$3\frac{9}{16}$	1	8
$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{16}$	$1\frac{1}{16}$	8
4	$4\frac{1}{4}$	$4\frac{9}{16}$	$1\frac{1}{8}$	8
$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{16}$	$1\frac{1}{4}$	8
5	$5\frac{5}{16}$	$5\frac{5}{8}$	$1\frac{1}{4}$	8
6	$6\frac{5}{16}$	$6\frac{3}{4}$	$1\frac{3}{8}$	8
7	$7\frac{7}{8}$	$7\frac{11}{16}$	$1\frac{1}{2}$	8
8	$8\frac{3}{8}$	$8\frac{11}{16}$	$1\frac{5}{8}$	8
10	$10\frac{13}{32}$	$10\frac{13}{16}$	$1\frac{3}{4}$	8

Table No. 153. (Continued.)

Static Hd.	Size, and Weight per foot.	Static Hd.	Size, and Weight per foot.
[illegible]	1 inch A, 4 lbs.	300	1¾ inch AA, 8½ lbs.
[illegible]	1 inch AA, 4½ lbs.		2 inch Waste, 3 lbs.
[illegible]	1 inch AAA, 6 lbs.	25	2 inch D, 4 lbs.
[illegible]	1¼ inch E, 2 lbs.	50	2 inch C, 5 lbs.
25	1¼ inch D, 2½ lbs.	75	2 inch B, 6 lbs.
50	1¼ inch C, 3 lbs.	100	2 inch A, 7 lbs.
50	1¼ inch B, 3 lbs. 11 oz	200	2 inch AA, 8 lbs. 14 oz.
[illegible]	¼ inch A, 4 lbs. 11 oz	300	2 in. AAA, 10 lbs. 11 oz.
[illegible]	1¼ inch AA, 5¾ lbs.		2½ inch Waste, 4 lbs.
[illegible]	1¼ in. AAA, 6¾ lbs.		2½ inch Waste, [illegible] lbs.
50	1½ inch E, 2 lbs.	50	2½ inch, 3-16 inch thick, 7 lbs. 13 oz.
50	1½ inch D, 3 lbs.	100	2½ in., ¼ in. thick, 10 lbs. 10 oz.
25	1½ inch D, 3½ lbs.	150	2½ in., 5-16 in. thick, 13 lbs. 10 oz.
50	1½ inch C, 4¼ lbs.	200	2½ in., ⅜ in. thick, 16 lbs. 11 oz.
175	1½ inch B, 5 lbs.		3 inch Waste, [illegible] lbs.
200	1½ inch A, 6¼ lbs.		3 inch Waste, 5 lbs.
250	1½ inch AA, 7 lbs.	75	3 in., 3-16 in. thick, 9 lbs. 4 oz.
300	1½ inch AAA, 8 lbs.	100	3 in., ¼ in. thick, 12 lbs. 9 oz.
75	1¾ in. D, 3 lbs. 10 oz.	130	3 in., 5-16 in. thick, 16 lbs.
100	1¾ inch C, 4 lbs.	150	3 in., ⅜ in. thick, 19 lbs. 9 oz.
150	1¾ inch B, 5 lbs.		
[illegible]	1¾ inch A, 6 lbs. 7 oz.		

Table No. 153.

Lead Pipe Table

Giving the actual thickness and weight per lineal foot of all commonly used sizes and weights of pipe, together with the maximum static head in feet that each will resist under average conditions in practice, without rupture.

Static Hd.	Sec.	Size, and Weight per foot
300		⅛ inch, 3 oz.
250		¼ inch E, 5 oz.
100		⅜ inch D, 7 oz.
150		⅜ inch, 10 oz.
200		⅜ inch C, 14 oz.
250		⅜ inch B, 1 lb.
300		⅜ inch A, 1 lb. 2 oz.
400		⅜ in. A A, 1 lb. 5 oz.
500		⅜ in. AAA, 1 lb. 12 oz.
100		7-16 inch, 9½ oz.
100		½ inch D, 9 oz.
150		½ inch D, 10 oz.
200		½ inch D, 12 oz.
250		½ inch C, 1 lb.
300		½ inch B, 1 lb. 3 oz.
350		½ inch A, 1 lb. 10 oz.
400		½ inch AA, 2 lbs.
450		½ inch, 2 lbs. 8 oz.
500		½ inch AAA, 3 lbs.
100		⅝ inch E, 12 oz.
150		⅝ inch D, 1 lb.
200		⅝ inch D, 1 lb. 4 oz.
250		⅝ inch C, 1 lb. 7 oz.
300		⅝ inch B, 2 lbs.
350		⅝ inch A, 2 lbs. 8 oz.
400		⅝ inch AA, 2¾ lbs.
500		⅝ inch A A A, 3½ lbs.
100		¾ inch E, 1 lb.
150		¾ inch D, 1 lb. 8 oz.
200		¾ inch C, 1 lb. 12 oz.
250		¾ inch B, 2 lbs. 3 oz.
300		¾ inch A, 3 lbs.
350		¾ inch AA, 3½ lbs.
400		¾ inch, 4 lbs.
500		¾ inch AAA, 4 lbs. 14 oz.
100		1 inch E, 1⅛ lbs.
150		1 inch D, 2 lbs.
175		1 inch D, 2¾ lbs.
200		1 inch C, 2½ lbs.
250		1 inch B, 3¾ lbs.

WATER METERS.

The American people will waste water; no amount of pleading with them, notices of "short supply," etc., permanently reduce the per capita consumption. Our water-sheds are fast being depleted of forests, and we cannot rely on them for much more than one-half the water they once would furnish per sq. mile, when growing crops take the place of the forests. The day has arrived for many, and will soon arrive for all municipalities, when it will be impossible to provide for other than legitimate use of water. Every water-works man, not tied by political or other bonds that in a measure compel him to say little, is or ought to be in favor of a METER SYSTEM, knowing it to be a necessary adjunct to every water-works that is to be operated for minimum expense.

Meters do not prevent legitimate use, but do exert a restraining influence over waste of water.

25 small drops per minute = 1 gallon per day.

800 small drops per minute = 1 barrel per day, or sufficient for all ordinary requirements of an average family.

It is the aggregate of such small leaks fully as much as those more noticeable, that can make the meter "go round" and create "short supply." Where meters are used such small leaks are stopped as soon as noticed. Where meters are not used it will pay any department to inspect all fixtures frequently and place at expense of department new washers where required.

Washers are cheaper than postage, while notification by mail does not insure stopping the leak. The advantage of meters is best shown by example, two comparable ones are taken; No. 1 is from the author's practice. City No. 1 population, 8,000, 25 miles from City No. 2, with same population. Industrial and other uses of water same in both places. No. 1 supplied by pumping from two shallow wells fed from no other source than adjacent 1.25 sq. miles of steep rocky water-shed, draining into 30 acres of sandy soil. 90 per cent. of services metered, per capita consumption, 50 gallons per day, with no fear of short supply in dry season of 1900. No. 2 supplied from 4.5 sq. miles of similar water-shed, *combined reservoir* capacity in excess of 500 millions

[illegible]

[illegible] adoption [illegible] additional supply [illegible] sufficient to pay the cost [illegible]

[illegible] beginning [illegible] other well [illegible] be filtered, an[illegible] construct [illegible] filters about one

The [illegible] investigation at Philade[illegible] [illegible] while preparing his report, which

Table No. 154.

FOR WATER AT VARIOUS POPULAR RATES PER 1000 GALLONS.

COST PER 1000 GALLONS							
5 Cents	6 Cents	8 Cents	10 Cents	15 Cents	20 Cents	25 Cents	30 Cents
$0.007	$0.009	$0.011	$0.015	$0.021	$0.030	$0.037	$0.045
0.015	0.018	0.024	0.030	0.045	0.060	0.075	0.090
0.022	0.027	0.036	0.045	0.066	0.090	0.112	0.135
0.030	0.036	0.048	0.060	0.090	0.120	0.150	0.180
0.037	0.049	0.060	0.075	0.111	0.150	0.187	0.224
0.075	0.090	0.120	0.150	0.225	0.299	0.374	0.449
0.112	0.135	0.180	0.224	0.336	0.449	0.561	0.673
0.150	0.180	0.239	0.299	0.450	0.598	0.748	0.898
0.188	0.224	0.299	0.374	0.564	0.748	0.935	1.122
0.224	0.269	0.359	0.449	0.448	0.898	1.122	1.346
0.262	0.314	0.419	0.524	0.786	1.047	1.309	1.571
0.299	0.350	0.470	0.598	0.897	1.197	1.496	1.795
0.337	0.404	0.539	0.673	1.011	1.346	1.683	2.020
0.374	0.449	0.598	0.748	1.122	1.496	1.870	2.244
0.748	0.898	1.197	1.496	2.244	2.992	3.740	4.488
1.122	1.346	1.795	2.244	3.366	4.488	5.610	6.732
1.496	1.795	2.393	2.992	4.488	5.984	7.480	8.976
1.870	2.244	2.992	3.740	5.610	7.480	9.350	11.220
2.244	2.692	3.590	4.488	6.732	8.976	11.220	13.464
2.618	3.142	4.189	5.236	7.854	10.472	13.090	15.708
2.992	3.590	4.787	5.984	8.976	11.968	14.961	17.951
3.366	4.039	5.385	6.732	10.098	13.464	16.832	20.197
3.74	4.488	5.984	7.480	11.122	14.961	18.701	22.441
7.48	8.976	11.968	14.961	22.443	29.922	37.402	44.882
11.22	13.46	17.95	22.44	33.664	44.88	56.10	67.32
14.96	17.95	23.94	29.92	44.885	59.84	74.80	89.77
18.70	22.44	29.92	37.40	56.103	74.80	93.50	112.20
22.44	26.92	35.90	44.88	67.323	89.76	112.20	134.64
26.18	31.41	41.89	52.36	78.543	104.72	130.90	157.08
29.92	35.90	47.87	59.84	89.766	119.68	149.61	179.51
33.66	40.39	53.85	67.32	100.986	134.64	168.31	201.97
37.40	44.88	59.84	74.80	111.22	149.61	187.01	224.41
74.81	89.76	119.68	149.61	224.43	299.22	374.03	448.82
112.20	134.64	179.53	224.41	336.64	448.83	561.04	673.24
149.61	179.53	239.37	299.22	448.85	598.44	748.05	897.66
187.02	224.41	299.22	374.00	561.03	748.05	935.06	1122.07
224.41	269.29	359.06	448.81	673.23	897.66	1122.07	1346.49
261.81	314.18	418.90	523.63	785.43	1047.27	1309.08	1570.88
299.22	359.06	478.75	598.44	897.66	1196.88	1496.10	1795.32
336.60	403.94	538.30	673.24	1009.86	1346.49	1683.11	2019.74
374.00	448.83	598.44	748.05	1122.06	1496.10	1870.12	2244.15

WATER MOTORS.

ere are two classes in popular use. Ist., Jet; 2nd., 1.

the first class, impact wheels are included, and the work performed is by impact of the water 50 per cent is the maximum theoretical efficiency. class of wheel seldom give over 40 per cent., and t average over 35 per cent. efficiency. By proper-rving and shaping the buckets, advantage of pres-of the water is obtained, and the author has re-d an efficiency of 62 per cent. with a well-known r. Everything considered, it is not safe to figure ore than 50 per cent., and on this basis the amount ater used by a motor per horse power, is double given in Table No. 155.

ston motors are generally constructed so that a is made to revolve by motion imparted to it by ral pistons working under pressure after the man-f *steam pistons.*

Friction in such a motor is considerable, and under average conditions they cannot compete with Class No. 1.

There are locations where water pressure engines can be used to advantage, as in elevating a portion of water above the source of supply.

One horse-power delivered from a water motor of [illegible] per cent. efficiency, under 200 feet head each day of [illegible] working days in a year, would require over 7000000 gallons of water to operate the motor. When interest account and all other items are considered, there are few cases in the States, gravity or pumping, where this amount of water could be delivered at a profit for less than five cents per 1000 gallons. At this price the one horse-power would cost $350. per annum, or about ten times its cost if furnished by gas or oil engine.

It needs no argument to show that where power is in constant use throughout the working day, that water motors should not be used, if the supply is to be furnished by a system intended for domestic use and industrial purposes, other than power and fire protection.

Every water motor should be metered, if not, in nine cases out of ten, it will cost $10 to deliver the water for every dollar of income from this source.

Where there is ample pressure, supply and storage and water is delivered by gravity, the limited use of motors to supply intermittent power is not objectionable. In the author's experience, reduced to 200' head motors for such intermittent power have used per annum in millions of gallons, ½ x horse-power of motor; that is, 10 h. p. motor will use 5,000,000; 4 h. p. motor, 2,000,000 gallons per annum, etc. A few examples taken from practice, (reduced to 200' head) are given in the following table.

ACTUAL WATER USED BY WATER MOTORS FOR VARIOUS PURPOSES UNDER 200' HEAD.	Water used by Motor in Millions of Gallons, per Year
Average daily newspaper office, (2,000 circulation), with 1 cylinder and 3 job presses, requiring 5 h. p. steam, . .	2.5
Store, 3 story elevator, 1 ton capacity, average load 1,000 lbs., 15 trips per day, .	3.
Coffee Grinders, average in average store,	0.5
Ice Cream Freezer, for season in average bakery, ...	0.2
Sausage Grinder, for season in average meat market, ...	0.2
Fans in Restaurant, for season, average per fan.	0.1
Dentist Office, ...	0.2

Table No. 155.

Head. Lbs.	Head. Feet.	Velocity of discharge in ft. per second.	No. of United States Gallons of 231 Cubic Inches discharged per minute. $\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	Lbs.
10	23.1	38.58	0.37	1.48	3.30	5.90	13.2	23.6	36.8	53.2	72.2	94.4	119	148	178	212	289	378	478	590	10
15	34.7	47.25	0.45	1.81	4.02	7.23	16.2	28.7	45.0	65.1	88.4	116	146	181	218	260	354	463	586	723	15
20	46.2	54.55	0.52	2.09	4.66	8.35	18.7	33.4	52.0	75.3	102	134	169	209	252	300	409	534	676	835	20
25	57.8	60.99	0.58	2.33	5.23	9.33	20.9	37.2	58.2	84.1	114	149	189	233	282	336	457	597	756	933	25
30	69.3	66.82	0.64	2.56	5.71	10.2	22.8	40.9	63.7	92.2	125	164	207	256	309	368	501	654	828	1022	30
35	80.9	72.16	0.69	2.76	6.16	11.0	24.7	44.2	68.8	99.6	135	177	223	276	334	397	541	707	895	1104	35
40	92.4	77.14	0.74	2.95	6.60	11.8	26.4	47.2	73.6	106	144	189	239	295	357	425	578	755	956	1180	40
45	104.0	81.83	0.78	3.13	6.99	12.5	28.0	50.2	78.1	113	153	200	253	313	378	450	613	801	1014	1252	45
50	115.5	86.26	0.82	3.30	7.37	13.2	29.5	52.8	82.3	119	161	211	267	330	399	475	646	845	1069	1320	50
55	127.1	90.46	0.86	3.46	7.73	13.8	30.9	55.4	86.3	125	169	221	280	346	418	498	678	886	1122	1385	55
60	138.6	94.49	0.90	3.62	8.08	14.5	32.3	57.8	90.1	130	177	231	293	362	437	520	708	925	1171	1446	60
65	150.2	98.35	0.94	3.77	8.40	15.1	33.6	60.2	93.8	136	184	241	305	377	455	542	737	963	1219	1506	65
70	161.7	102.06	0.97	3.91	8.73	15.6	34.9	62.5	97.4	141	191	250	316	391	472	562	765	999	1265	1561	70
75	173.3	105.65	1.01	4.04	9.03	16.2	36.1	64.6	101	146	198	259	327	404	488	582	792	1034	1309	1616	75
80	184.8	109.11	1.04	4.18	9.33	16.7	37.8	66.6	104	150	204	267	338	418	504	601	818	1068	1352	1669	80
85	196.4	112.46	1.07	4.31	9.62	17.2	38.5	68.8	107	155	210	275	348	431	520	620	843	1101	1394	1720	85
90	207.9	115.72	1.10	4.43	9.89	17.7	39.6	70.8	110	160	217	283	358	443	535	637	867	1133	1434	1770	90
95	219.5	118.89	1.13	4.55	10.2	18.2	40.7	72.8	113	164	223	291	368	455	550	655	891	1164	1474	1820	95
100	231.1	121.98	1.16	4.67	10.4	18.7	41.7	74.6	116	168	228	299	378	467	564	672	914	1194	1512	1866	100
105	242.6	125.00	1.19	4.78	10.7	19.1	42.8	76.5	119	172	234	306	387	478	578	688	937	1224	1549	1912	105
110	254.2	127.94	1.22	4.90	10.9	19.6	43.8	78.3	122	177	239	313	396	490	591	705	959	1253	1586	1957	110
115	265.7	130.82	1.25	5.01	11.2	20.0	44.8	80.1	125	181	245	320	405	501	605	720	980	1281	1621	2002	115
120	277.3	133.63	1.27	5.12	11.4	20.4	45.7	81.8	127	184	250	327	414	512	618	736	1001	1308	1656	2044	120
125	288.8	136.38	1.30	5.22	11.7	20.9	46.7	83.5	130	188	255	334	422	522	630	751	1022	1335	1691	2086	125
130	300.4	139.08	1.33	5.32	11.9	21.3	47.6	85.1	133	192	260	341	431	532	643	766	1042	1362	1724	2128	130

Actual discharge will be less than theoretical one given above, varying with form of nozzle or tube through which water flows. For ring nozzle 60 to 65 per cent., and for good form of tapering smooth nozzle about 80 per cent., can be assumed as actual discharge.

power of water = (quantity in cu. ft. per min- ·ad or fall in feet × 62.5) ÷ 33000. A recognized d make of Turbine is best to adopt for low or te heads. As a rule the horizontal pattern is ole, and will be most efficient. The efficiency ·y, depending on the design, proportion of wheel vork required of it, and many other points that its of this work will not permit to be discussed. ·t safe to figure on more than 80 per cent. effi- though 90 + per cent. efficiency has been re- with full gate. Each ⅛ closing of gate will re- ıe efficiency of a good horizontal turbine about 7 ıt. This loss can be partly counteracted by using : more properly proportioned wheels on the one

revolutions of a wheel and the discharge in cu. ·y as the square root of the head, and the power ›ped as the square root of the cube of the head. .esigning, the velocity of the water can be assumed 5 per cent. of the theoretical velocity given in No. 156, while under average conditions, if the ty of the wheel is 62.5 per cent. of that of the wa- e best results will be obtained. It will be noticed his corresponds with the weight of a cu. ft. of .

D. Wood & Co. give the following table of horse- : of some of their Turbines.

Table No. 157.

E-POWERS OF TURBINES, SINGLE WHEELS, SMALLER SIZES.

ter hes. le el.	HEIGHT OF FALL.				
	10 Feet.	15 Feet.	20 Feet.	25 Feet.	30 Feet
	HORSE-POWERS.				
	9.47	17.25	26.4	37	48.8
	13.9	25.2	39.6	55.2	72.2
	19.8	35	54.5	76.9	100
	24	44	68	85	126
	32	62	94	135	173
	40.7	80	120	175	220
½	53	95	156	218	280
	67	110	193	262	340

[illegible] exposed metal
[illegible] is assumed to
[illegible] not always th
[illegible] of flat
[illegible] the wind.

[illegible] pressure on
[illegible] flat surface
[illegible] circular
[illegible] the top

[illegible] height of star
[illegible] against spira
[illegible]
[illegible] diam. [illegible] ......
[illegible] P.

[illegible] value
[illegible] rec
[illegible] Bridge [illegible] show tha
[illegible] large than
[illegible] the maximum observe
[illegible] small plate it was
[illegible] Russian observations sh

d in net tons we have,

.012 × diam. × height......................(c)

r value thought necessary can be substituted ring a different value to the above and following tions. Good judgment must be used.

entre of pressure given by (c) is at centre of and THE FORCE TENDING TO BLOW OVER THE E, (T) = (c) × ½ height or 0.006 × diam. × height. To resist this force when the standmpty, not anchored or guyed, we have simply,

t of standpipe (W) × ½ its diam ....(d)

diam. is great in proportion to height, (d) will

st be equal to or>(T) or the standpipe will er, unless it is properly anchored or guyed, or t must also be anchored to resist being moved zontal direction by the wind; for the resistance generally about one-fourth its weight, is not as most cases as horizontal component of P_s at

RY FOUNDATION:—Area should be such that the esultant pressure of maximum wind strain and alls well within the circumference. If possible too expensive, carry masonry to rock base. If ion is in quick sand or other treacherous matere piles (preferably oak) as close to each other as l will permit; saw them off level well below the e; make cross grillage of railroad rails or other steel. and anchor bolts to it; bed the whole in icrete and carry it to the surface. Always carry y well below the frost line and batter, or step ter outside slope so frost will not "lift" it. The onditions should be complied with whether or masonry is necessary to comply with requireof stability as below given. Do not erect standr other tall and narrow structures on soil subject ations of railroad trains or heavy machinery unery precaution is taken to counteract its effect.

RIBUTED WEIGHT OF MASONRY ought to be such eight on it per sq. ft. will not exceed

9 tons for good concrete,
7 " " " sandstone,
4.5 " " " brick work,
4. " " " concrete.

[illegible] Weight of Masonry.—As shown above (d) [illegible] (T). By uniting sufficient masonry well [illegible] stand-pipe, so that the two will act as one [illegible] masonry can resist (T). The lever arm, [illegible] through which (T) acts will be increased by [illegible] masonry and we have

$$\left([illegible] - \begin{matrix}\text{Weight of}\\ \text{Standpipe}\end{matrix} \right) \times \tfrac{1}{2}\ \text{diam.} = $$

$$ [illegible]\ P_{s.e} \left(\tfrac{1}{2}\ \text{height} + \begin{matrix}\text{Depth of}\\ \text{Masonry}\end{matrix} \right) $$

[illegible] we obtain

$$ [illegible] = \frac{P_{s.e} \left(\tfrac{1}{2}\ \text{height} + \begin{matrix}\text{depth of}\\ \text{masonry}\end{matrix} \right)}{[illegible] \times \text{diameter.}} - \begin{matrix}\text{Weight}\\ \text{of}\\ \text{Standpipe}\end{matrix} $$

Table No. 158.

[illegible] AND TANK TABLE.

[illegible] Thickness in Thirty Seconds of [illegible] Plates of Good Iron or Steel [illegible] in the Construction of Ex- [illegible] and Tanks of Various [illegible] Diameters and Heights.

[illegible]	Diameter of Stand-pipe in Feet.								
[illegible]	[illegible]	[illegible]	15	18	20	25	30	35	40
[illegible]									

No. 158 gives the actual thickness of bottom ed in American practice as deduced from ac- surements of over 150 successful standpipes s. The thickness of top plates vary from 1/8" seldom exceeding 1/4"); 3-16" is most common s, though everything considered, especially in ates, 1/4" with angle iron stiffening ring is best. ss of plates between bottom and top plates re- proportion to their distance from bottom.
ble covers all ordinary practice. The author ined from filling it out by interpolation or cal- believing that though the problems all admit etical solution, in such cases practical data is le. For many reasons, lack of uniformity in of plates, unequal sheer on rivets, lack of per- wledge of wind strains, weak spots in founda- ., only an approximate determination of the a riveted joint can be obtained; with this ap- te, no other calculation depending on it can be When there is no precedent to guide, it is al- ell to get the opinion of reliable constructors, ke a specialty of this class of work, while those with Calculus and other higher mathematics, such works as "Elasticity and Resistance of ls of Engineering," by Wm. H. Burr, C. E., of. of Mechanics at Rens. Poly. Inst., now of ia,) of great assistance when standpipe or other al material is under consideration.

Tanks on Towers.

s standpipe is constructed at location much he general level of points of discharge in the tion system, the water in the lower two-thirds fifths of the standpipe is not available for effi- e protection or other use. When adopted height f standpipe exceeds 50 feet above the surface, requently be found more economical to adopt ver and Tank system. Circumstances are often at it is best to adopt it for heights less than 50 ls generally constructed weight of tank + tower r is less than 1-5 of weight of standpipe (same nd height) + water; therefore necessary mason- dation to properly distribute the weight can be *proportionately* (nearly). Wind pressure on

tank and tower will seldom exceed one-half that on standpipe of same height, when tank height = about 1-5 height of tower. With round columns to tower the difference is generally greater. Though wind pressures are quickly obtained for any tower and tank, by equations under "Standpipes," an example showing the difference in pressures and other details is below given.

EXAMPLE:

20' × 100' standpipe, compared with 20' × 20' tank on 80' tower.

Leverage moment of wind pressure at base of standpipe, 1200 tons.	
Leverage moment of wind pressure of tank at foot of tower,	432 tons.
Leverage moment of wind pressure of average tower,	154 tons.
Total,	586 tons.

or less than one-half that on standpipe.

Weight of 20'×100' standpipe, average	45 tons.
Weight of water, (full),	974 tons.
Total,	1019 tons.
Weight of 80' tower, average,	25 tons.
Weight of 20'×20' tank, average,	12 tons.
Weight of water, (full),	195 tons.
Total,	232 tons.

or slightly in excess of 1-5 weight of standpipe + water. It will also be noted that the total weight of metal is but about 0.75 × weight of standpipe

The use of tanks made of wood, preferably cypress, on steel, iron, wood or masonry towers is rapidly increasing, giving in many cases better satisfaction for less money than would be afforded by the metallic tank. Their use in connection with wind-mill outfits and artesian well supply is fast redeeming many parts of the arid regions without great cost for irrigation works. For isolated public institutions, private estates, small municipal water works, individual fire protection in cities, reserve for boiler supply, railroads, etc., such *tanks* on tower, roof or trestle have no substitute that *can*, under average conditions, compete in price, durability and safety.

By data under Tables No. 52 to 54B inclusive, calculations relative to capacity of and weight of water in andpipes and tanks will be facilitated.
Standard sizes and weights of tanks, towers, etc. are rried in stock, see part 2.

Hydraulic Notes.

(Other Hydraulic Notes will be found under appropriate headings elsewhere in this work.)

WEIRS,—Because of the exhaustive and reliable experiments of Mr. Francis, at Lowell Mass., with Weirs aving horizontal crest and vertical ends, and the tables at he and others have prepared, based on the data otained, such Weirs are generally used and within the mits below mentioned give accurate discharge. When e flow rapidly fluctuates and is small, the TRIANGULAR OTCHED Weir (isosceles triangle. angles, of 90°) is best o use. The use of such Weirs is rapidly increasing, specially in Southern California and other irrigated regions, where every Miners Inch of water has an intrinsic and practical value far beyond the conception of the average wasteful consumer in the Eastern and Central States Prof Jas. Thomsons formula based on experiments with flow from 2″ to 4″ in depth for such weirs is,

$Q = 0.317 \ H^{\frac{3}{2}}$ in which Q = discharge in cu. ft. per second, and H = depth over centre of Weir, measured in still water above stake below mentioned.

With Weirs having HORIZONTAL CREST and VERTICAL SIDES, area of section of water passing over Weir ought not to be > one-fifth area of section of stream just above it. For guide in construction of weir, discharge of stream can be taken at surface velocity of water in centre of stream × 0.8 area of section of stream where velocity is measured.

Bevel crest and sides, on down- stream side, 45° so that edges are ⅛″ or less in width. If Weir is to remain in stream for several days or more, use thin metal plate, cut from one piece if possible for crest and sides, firmly fastened to the plank. Drive stake so that its top is exactly level with the leveled, beveled crest or plate of Weir and far enough up-stream so that depth of flow when measured from top of stake will not be affected by *curve of discharge* over Weir.

When there is no velocity of approach, Table No. 150, gives discharge in cu. ft. per minute per inch in width of Weir for various depths of flow, from $\frac{1}{16}$" to 25". The discharge for even inches in depth (as given by bold face figures in first and last columns) is next to them in second and next to last columns; for example, discharge over weir 20" wide and 4" deep = 20 × 3.22 = 64.4 cu. ft. per minute. The discharge for parts of an inch in depth given in the top horizontal column are given in the second horizontal line; for example, discharge over Weir 10" wide and $\frac{5}{8}$" deep = 10 × 0.20 = 2.0 cu. ft per minute. Likewise discharge for inches and parts of an inch are given; for example, discharge over Weir 20" wide and $4\frac{1}{4}$" deep = 20 × 3.52 = 70.4 cu. ft. per minute.

If extreme accuracy is required, before making computation, deduct for each one-half inch in depth of flow, 0.1" from length of Weir; this provides for contraction of stream.

The length of Weir should be about four times depth of flow over it; while depth should not, if possible to avoid it, be less than 4" or more than 25". With very small streams this is impossible, and in such cases where extreme accuracy is required, as check on Weir measurement, deliver stream to and measure it in a tight box, the known capacity of which is > flow of stream for one minute. Small streams, as low as 10 to 12 gal- gallons per minute cannot be measured within 10 or 15 per cent. with a water pail or other small measure on account of the uncertainty within one or two seconds as to the instant when measure is exactly full.

The level of water in tail-race, (down stream from Weir) should be lower than crest of Weir by at least 1.5 × depth of flow over the crest, or partial vacuum will be created between the parabolic section of discharging stream and the Weir, increasing discharge for given depth of flow.

It will be found convenient to remember that ONE MILLION GALLONS PER DAY EQUALS:

1.547 cu. ft. per Second.
11.57 U. S. Gallons per Second.
77.3 California Miners' Inches.
92.82 Cubic Feet per Minute.
694.2 U. S. Gallons per Minute.
3.07 Acre-Feet per Day.
21 inches in depth of rain fell per year from one sq. mile.

Table No. 159.

DISCHARGE IN CUBIC FEET PER MINUTE PER INCH IN WIDTH (LENGTH) OVER WEIRS HAVING HORIZONTAL CREST AND VERTICAL ENDS, BOTH OF WHICH ARE BEVELED (45°) ON DOWN-STREAM SIDE, SO THAT EDGES ARE ⅛" IN WIDTH.

Inches	Parts of an Inch.	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	Parts of an Inch.	Inches
		.006	.01	.03	.05	.07	.09	.11	.14	.17	.20	.23	.26	.30	.33	.36		
1	.40	.43	.47	.51	.55	.60	.65	.70	.74	.78	.83	.87	.93	.98	1.03	1.08	.40	1
2	1.14	1.19	1.24	1.30	1.36	1.41	1.47	1.52	1.59	1.65	1.71	1.77	1.83	1.89	1.96	2.02	1.14	2
3	2.09	2.16	2.23	2.29	2.36	2.43	2.50	2.57	2.63	2.71	2.78	2.85	2.92	2.99	3.07	3.14	2.09	3
4	3.22	3.29	3.37	3.44	3.52	3.60	3.68	3.75	3.83	3.91	3.99	4.07	4.16	4.24	4.32	4.41	3.22	4
5	4.50	4.58	4.67	4.75	4.84	4.92	5.01	5.10	5.18	5.27	5.36	5.45	5.54	5.63	5.72	5.81	4.50	5
6	5.90	6.00	6.09	6.18	6.28	6.37	6.47	6.56	6.65	6.75	6.85	6.95	7.05	7.15	7.25	7.35	5.90	6
7	7.44	7.54	7.64	7.74	7.84	7.94	8.05	8.15	8.25	8.35	8.45	8.55	8.66	8.76	8.86	8.97	7.44	7
8	9.10	9.20	9.31	9.42	9.52	9.63	9.74	9.85	9.96	10.07	10.18	10.29	10.40	10.51	10.62	10.73	9.10	8
9	10.86	10.97	11.08	11.19	11.31	11.42	11.54	11.65	11.77	11.88	12.00	12.12	12.23	12.35	12.47	12.59	10.86	9
10	12.71	12.83	12.95	13.07	13.19	13.31	13.43	13.55	13.67	13.80	13.93	14.04	14.16	14.30	14.42	14.55	12.71	10
11	14.67	14.79	14.92	15.05	15.18	15.30	15.43	15.56	15.67	15.81	15.96	16.08	16.20	16.34	16.46	16.59	14.67	11
12	16.73	16.86	16.99	17.12	17.26	17.39	17.52	17.65	17.78	17.91	18.05	18.18	18.32	18.45	18.58	18.72	16.73	12
13	18.87	19.01	19.14	19.28	19.42	19.55	19.69	19.83	19.97	20.10	20.24	20.38	20.52	20.66	20.80	20.94	18.87	13
14	21.09	21.23	21.37	21.48	21.65	21.79	21.94	22.08	22.22	22.35	22.51	22.65	22.79	22.94	23.08	23.23	21.09	14
15	23.38	23.53	23.67	23.82	23.97	24.11	24.26	24.41	24.56	24.71	24.86	25.01	25.16	25.31	25.46	25.61	23.38	15
16	25.76	25.91	26.06	26.21	26.36	26.51	26.66	26.81	26.97	27.12	27.27	27.43	27.58	27.73	27.89	28.04	25.76	16
17	28.20	28.35	28.51	28.66	28.82	28.98	29.14	29.29	29.45	29.60	29.76	29.92	30.08	30.23	30.39	30.55	28.20	17
18	30.70	30.86	31.02	31.18	31.34	31.50	31.66	31.81	31.98	32.15	32.31	32.47	32.63	32.80	32.96	33.12	30.70	18
19	33.29	33.45	33.61	33.78	33.94	34.11	34.27	34.44	34.60	34.77	34.94	35.10	35.27	35.44	35.60	35.77	33.29	19
20	35.94	36.10	36.27	34.46	36.60	37.87	36.94	37.11	37.28	37.45	37.62	37.79	37.96	38.14	38.31	38.48	35.94	20
21	38.65	38.82	39.00	39.17	39.34	39.52	39.69	39.86	40.04	40.21	40.39	40.56	40.73	40.91	41.09	41.26	38.65	21
22	41.43	41.60	41.78	41.96	42.13	42.31	42.49	42.67	42.84	43.02	43.20	43.38	43.56	43.74	43.92	44.10	41.43	22
23	44.28	44.46	44.64	44.82	45.00	45.18	45.38	45.53	45.71	45.90	46.08	46.26	46.43	46.63	46.81	47.00	44.28	23
24	47.18	47.36	47.55	47.72	47.91	48.09	48.28	48.46	48.65	48.83	49.02	49.20	49.39	49.58	49.76	49.93	47.18	24

See text on preceding and following page.

VELOCITY OF APPROACH.—Mr. Francis determined that a velocity of approach of,

0.5 per second, depth 6" over weir, increased discharge but 1 per cent.

1.0 per second, depth 1' over weir, increased discharge but 2 per cent.

In most cases it can therefore be neglected when provision is made to reduce it to a minimum. When it must be considered, find by equations below given, (Francis formula,) in which,

L = length of weir notch in feet.

H = depth of water over weir as measured "at stake" after water is remaining at constant depth.

N = number of end contractions of discharging stream

Q = discharge in cu ft. per second.

We then have,

$Q = 3.33 \times (L - 0.1\ N \times H) \times H^{\frac{3}{2}}$ .... (a)

or when there are no end contractions we have,

Q, per ft. of weir, $= 3.33 \times L \times H \times \sqrt{H}$ .... (b)

Discharge in cu. ft. per minute $= 200 \times L \times H^{\frac{3}{2}}$ (c)

The head due to velocity of approach $= V^2 \div 2\,g$. $g =$ gravity $= 32.2$. In terms of Q as determined by above formula and area of section of stream (A), we have,

Head due to $V = Q^2 \div (64.4 \times A^2)$ and for the corrected head, h we have,

$$\left[\left\{\begin{array}{c}\text{measured}\\ \text{head over}\\ \text{stake}\end{array} + \begin{array}{c}\text{head due}\\ \text{to}\\ \text{velocity}\end{array}\right\}^{\frac{3}{2}} - \left\{\begin{array}{c}\text{head due}\\ \text{to}\\ \text{velocity}\end{array}\right\}^{\frac{3}{2}}\right]^{\frac{2}{3}}$$

Corrected discharge =

$3.33 \times [L - (0.1 \times N) \times h] \times h^{\frac{3}{2}}$ .... (d)

or with no end contractions, corrected discharge

$= 3.33 \times (L \times h) \times h^{\frac{3}{2}}$ .... (e)

MINERS' INCHES.

A miners inch of water is the amount flow- ; through an opening one square inch in area der a given head. As this head as adopted in dif- ent localities varies, from less than 4" to more than the value of the miners inch also varies. Again in : same locality, thickness of opening, its length and ght, relative area of opening and stream all tend to :y its amount. Where water is of great value, and term "miners inch" yet conveys a more specific aning to the people at large, than gallons or cu. ft. unit of time, its amount in one of such units has gen- lly been established by law. In British Columbia amount is 1.68 cu. ft. per second. In California 4" ıd is used (see Table No. 31) its legal amount or value).02 cu. ft. per second = 1.2 cu. ft. or 8.976 gallons minute = 12926.33 gallons per day, usually called ɔoo gallons.

:he amounts of discharge as given in Table No. 159 : quickly reduced to miners' inches by dividing by : cubic feet per minute in the miners' inch under ısideration. It is often more convenient to multiply the reciprocal.

Table No. 160.

REDUCTION TABLE.

The amount in California Miners' Inches Equals:

CUBIC FEET PER			U. S. GALLONS PER		
Second	÷	0.02	Second	÷	0.1496
"	×	50.	"	×	6.67
Minute	÷	1.2	Minute	÷	8.976
"	×	0.833	"	×	0.1114
Hour	÷	72.	Hour	÷	538.58
"	×	0.0138	"	×	0.0018
Day	÷	1728.	Day	÷	12926.33
"	×	0.0057	"	×	0.000077

If amount given in California Miners' inches is re- ired in any of above units, multiply it by any divisor divide by any multiplier as given opposite the unit *flow desired.*

[illegible] IN CALI-

[illegible] LENGTH.

[illegible]	[illegible]	[illegible]	[illegible]	M. L.
[illegible]	[illegible]	[illegible]	[illegible]	10.99
[illegible]	[illegible]	[illegible]	[illegible]	11.39
[illegible]	[illegible]	[illegible]	[illegible]	11.80
[illegible]	[illegible]	[illegible]	[illegible]	12.22
[illegible]	[illegible]	[illegible]	[illegible]	12.65
[illegible]	[illegible]	[illegible]	[illegible]	13.06
[illegible]	[illegible]	[illegible]	[illegible]	13.50
[illegible]	[illegible]	[illegible]	[illegible]	13.94
[illegible]	[illegible]	[illegible]	[illegible]	14.38
[illegible]	[illegible]	[illegible]	[illegible]	14.82
[illegible]	[illegible]	[illegible]	[illegible]	15.27
[illegible]	[illegible]	[illegible]	[illegible]	15.72
[illegible]	[illegible]	[illegible]	[illegible]	16.18
[illegible]	[illegible]	[illegible]	[illegible]	16.64
[illegible]	[illegible]	[illegible]	[illegible]	17.10
[illegible]	[illegible]	[illegible]	[illegible]	17.57
[illegible]	[illegible]	[illegible]	[illegible]	18.04
[illegible]	[illegible]	[illegible]	[illegible]	18.52
[illegible]	[illegible]	[illegible]	[illegible]	19.00
[illegible]	[illegible]	[illegible]	[illegible]	19.48
[illegible]	[illegible]	[illegible]	[illegible]	19.98
[illegible]	[illegible]	[illegible]	[illegible]	20.47
[illegible]	[illegible]	[illegible]	[illegible]	20.97
[illegible]	[illegible]	[illegible]	[illegible]	21.47
[illegible]	[illegible]	[illegible]	[illegible]	22.47
[illegible]	[illegible]	[illegible]	[illegible]	23.50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[redacted]

FLOW OVER DAMS, ETC.

ℕITH SHORT LEVEL CREST AND NO BACK WATER.

= length of Weir or overflow.

= Depth of water over dam, measured back of curve, as in case of small Weirs.

= co-efficient; we then have, for Q (discharge in cu. ft. per second,) $Q = A \times L \times H^{\frac{3}{2}}$.

The value of A will depend on the relative length of ·erflow and width of stream or reservoir back of dam ; follows.

When length of overflow equals,

$1.0 \times$	width of reservoir.			$A = 3.541.$*
$0.9 \times$	"	"	"	$A = 3.509.$
$0.8 \times$	"	"	"	$A = 3.444.$
$0.7 \times$	"	"	"	$A = 3.396.$
$0.6 \times$	"	"	"	$A = 3.348.$
$0.5 \times$	"	"	"	$A = 3.3.$
$0.4 \times$	"	"	"	$A = 3.246.$
$0.3 \times$	"	"	"	$A = 3.198.$
$0.2 \times$	"	"	"	$A = 3.166.$

*In this case H should be $<$ ¼ depth of reservoir. Vhen $L \times H <$ one-fifth section of stream or reservoir, 'elocity of approach (V) can be neglected as it seldom vill exceed 1 per cent., but when $L \times H >$ the ⅕ section ve have,

$Q = 3.487 \times L \times H \times \sqrt{H + 0.0349 \times S^2}$ in which xpression S = mean surface velocity, corrected for air urrents.

FLOW OVER WASTE WEIRS OR OVERFLOWS OF DAMS.

When Weir crest is level and about three feet wide Ir. Francis suggested the formula,

$Q = 3.01208 \times L \times H^{1.53}$ in which Q, L and H. repesent same quantities as on pages 268.

With the same width of crest, (3 ft.) Mr. Backwell sed the following formula,

$Q = 0.66 \times M \times L \times \sqrt{2g} \times H^{2}$ in which Q, L. g and [represent same quantities as on page 268, while the npirical quantity M he determined by experiment to e as given in Table No 162. (taken from J. T. Fanings "*Hydraulic and* Water Supply Engineering",.

Table No. 162.

[illegible] Weir Crests Three Feet Wide.

[illegible]	[illegible]	[illegible]	[illegible]	6 feet long level.	10 feet long level.	10 feet long inclined, 1 in 18.
[illegible]	[illegible]	[illegible]	M	M	M	M
[illegible]	[illegible]	[illegible]	[illegible]		.381	.467
[illegible]	[illegible]	[illegible]	[illegible]		.479	.495
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		.515
[illegible]	[illegible]	[illegible]			.518	
[illegible]	[illegible]		[illegible]	[illegible]	.513	.543
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]			[illegible]	.507
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.480	
[illegible]				[illegible]	.455	
[illegible]				[illegible]		
[illegible]						

[illegible] mentioned in above table [illegible] direction of discharge.

[illegible] Natural Channels.—The most reliable [illegible] obtained by use of some form of modern [illegible]. When, however, the velocity is obtained [illegible] by the use of floats, the mean velocity [illegible] mean of observed velocities of [illegible] equidistantly across the stream. If [illegible] velocity only is obtained, mean velocity

then have,

$$= 1.3 \times \sqrt{H \times \frac{S}{C}} \text{.............................(a)}$$

$$= 1.3 \times \sqrt{H \times \frac{S^3}{C}} \text{.............................(b)}$$

$$= 840212 \times \sqrt{H \times \frac{S^3}{C}} \text{.............................(c)}$$

solving (a), (b) or (c) almost any practical question ive to discharge, necessary grade, etc., of Con-, Aqueducts, Canals, Ditches, etc., is answered enough for most purposes.

pplied to the old Croton aqueduct, length 40 miles, 125; area, 56.64 sq. ft.; nominal capacity, 60 millions 11.1 cu. ft. per second, it gives capacity within 3 cent.

he aqueduct is reported to have carried 100 millions day and if so, it was working under pressure head.

ew conduits, canals, etc., designed by aid of (a), (b) l (c) will in most cases deliver more than the amount culated, but when algae growths, tuberculation, de-sits, etc., are properly considered, the formula give ults probably as near correct as when Kutters or ler complicated formula is used.

In using (a), (b) and (c) it will be found convenient to member

1st. That $\frac{S}{C}$ for rectangular channels is a maximum hen depth of flow = one-half the width.

2nd. That the discharge of circular conduits (not nder pressure) is maximum when the depth of flow is 9 × the diameter of conduit, approximately.

3rd. That the hydraulic mean radius of a circular nduit = diam. ÷ 4, and for other conduits, channels, c. = *area section* ÷ contour or wet perimeter.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	feet per min
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.00	20
[illegible]	[illegible]	[illegible]	[illegible]	1.87	2.19	2.50	25
[illegible]	[illegible]	[illegible]	1.87	2.25	2.62	3.00	30
[illegible]	[illegible]	[illegible]	[illegible]	2.62	3.06	3.50	35
[illegible]	1.75	[illegible]	[illegible]	3.00	3.50	4.00	[illegible]
[illegible]	1.97	[illegible]	2.81	3.37	3.94	4.50	[illegible]
1.87	2.19	2.50	[illegible]	3.75	4.37	[illegible]	[illegible]
2.25	2.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.81	3.28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18.75	[illegible]	[illegible]	31.25	[illegible]	43.75	[illegible]	[illegible]

HYDRAULIC RAMS.

PRINCIPLE INVOLVED IN HYDRAULIC RAMS IS CONSIDERED UNDER "WATER HAMMER."

he approximate discharge of a good ram or "set of s," each with a separate "drive pipe" but if desired a one discharge pipe, where all pipes are proportod to the work required, can be found by the following formula.

$$q = \frac{Q \times F \times 0.65}{L} \text{ in which}$$

= flow of available stream or springs in gallons minute.

= fall to ram or rams from stream or springs in

= lift or height water is elevated in feet.

= quantity of water elevated in gallons per min-

length of discharge pipe< ¼ mile, under average itions,

Then L = $10 \times F$, q = from 0.1 to $0.066 \times Q$.

Then L = $5 \times F$, q = from 0.15 to $0.13 \times Q$, or apximately one seventh of available water can be eleed 5 ft. for each foot of fall, or less in proportion as is increased.

able No. 142 will assist in determining proper size onnecting pipes, it being remembered that for disrge given in the table all the head is used, and the es do not discharge under pressure.

he "American Well Works" give the following venient tables. (No. 164 and 165).

Table No. 164.

HYDRAULIC RAM DATA.

um Fall of Water, in Feet Ram, elevating water to ght below	2	2	2	3	4	5	6	7	8	10	12
ht water may be eleed, feet	4	6	8	15	24	35	48	63	80	100	120
gth of Drive Pipe, feet	12	12	12	15	20	30	40	50	60	75	95
portion of water entering m that is elevated	2-7	1-5	1-7	2-17	1-10	1-12	1-14	2-31	1-17	1-18	1-20
cent. of useful effect of ower expended	80	78	75	72	68	62	57	53	48	43	38

Efficiency given is approximate only.

... pipe.

... —Pressure in lbs. ... velocity of wind in ... should be multiplied by ... surface is oblique to ... note on page ... correct for all excep... than the above rule, w...

Table No. 166.

... SIZES OF STE... MILE WIND PER ... WALLING ...

(U. S. Wind Engine and Pump Co.)

Power of Mill estimated in an 18-mile wind.

Diameter of Wind Wheel	Five Feet Elevation.				Ten Feet Elevation.				Fifteen Feet Elevation.			
	Size of Elevator Bucket in Inches.	Speed in Feet per Minute.	Capacity per Hour, in Gallons.	Price of Elevator.	Size of Elevator Bucket in Inches.	Speed in Feet per Minute.	Capacity per Hour, in Gallons.	Price of Elevator.	Size of Elevator Bucket in Inches.	Speed in Feet per Minute.	Capacity per Hour, in Gallons.	Price of Elevator.
12 feet	3 x 4	500	18,700	$40 00	3 x 4	318	11,900	$45 00	2 x 3	465	8,700	$40 00
13 feet	3 x 5	471	22,000	45 00	3 x 4	371	13,900		2 x 3	545	10,200	
16 feet	4 x 6	445	33,300	65 00	3 x 5	451	21,100	50 00	3 x 4	412	15,400	50 00
22 feet	4 x 12	421	63,000	78 00	4 x 6	535	40,000	70 00	4 x 6	389	29,100	75 00
25 feet	4 x 12	544	81,400		4 x 8	517	51,600	75 00	4 x 6	503	37,600	
30 feet	4 x 18	522	117,200	86 00	4 x 12	497	74,300	84 00	4 x 8	542	54,100	80 00
36 feet	4 x 32	423	168,700	100 00	4 x 18	477	107,000	92 00	4 x 12	321	77,900	90 00
40 feet	4 x 32	522	208,300		4 x 24	441	132,100	100 00	4 x 18	428	96,100	100 00
50 feet	2, 4 x 26	502	325,400	90 00	4 x 32	517	206,400	110 00	4 x 24	502	150,200	110 00
60 feet	2, 4 x 36	522	438,600	110 00	2, 4 x 36	458	297 200	120 00	4 x 32	542	216,300	125 00

See Page 264.

When constant power or flow of water is required, machine or pump should be connected by "cut out" coupling to oil, gas or other engine or water wheel, to be used when power of wind is deficient.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table No. 170.

VING IN PER CENT. FOR EACH DEGREE OF INCREASE IN TEMPERATURE OF FEED WATER HEATED.

Boiler steam pressure in lbs. per sq. in above atmosphere.

Initial Temp. of Feed.	0	20	40	60	80	100	120	140	160	180	200	Initial Temp.
32°	.0872	.0861	.0855	.0851	.0847	.0844	.0841	.0839	.0837	.0835	.0833	32°
40	.0878	.0867	.0861	.0856	.0853	.0850	.0847	.0845	.0843	.0841	.0839	40
50	.0886	.0875	.0868	.0864	.0860	.0857	.0854	.0852	.0850	.0848	.0846	50
60	.0894	.0883	.0876	.0872	.0867	.0864	.0862	.0859	.0856	.0855	.0853	60
70	.0902	.0890	.0884	.0879	.0875	.0872	.0869	.0867	.0864	.0862	.0860	70
80	.0910	.0898	.0891	.0887	.0883	.0879	.0877	.0874	.0872	.0870	.0868	80
90	.0919	.0907	.0900	.0895	.0891	.0887	.0884	.0882	.0879	.0877	.0875	90
100	.0927	.0915	.0908	.0902	.0899	.0895	.0892	.0890	.0887	.0885	.0883	100
110	.0936	.0923	.0916	.0911	.0907	.0903	.0900	.0898	.0895	.0893	.0891	110
120	.0945	.0932	.0925	.0919	.0915	.0911	.0908	.0906	.0903	.0901	.0899	120
130	.0954	.0941	.0934	.0928	.0924	.0920	.0917	.0914	.0912	.0909	.0907	130
140	.0963	.0950	.0943	.0937	.0933	.0929	.0925	.0923	.0920	.0918	.0916	140
150	.0973	.0959	.0951	.0946	.0941	.0937	.0934	.0931	.0929	.0926	.0924	150
160	.0982	.0968	.0961	.0955	.0950	.0946	.0943	.0940	.0937	.0935	.0933	160
170	.0992	.0978	.0970	.0964	.0959	.0955	.0952	.0949	.0946	.0944	.0941	170
180	.1002	.0988	.0981	.0973	.0969	.0965	.0961	.0958	.0955	.0953	.0951	180
190	.1012	.0998	.0989	.0983	.0978	.0974	.0971	.0968	.0964	.0962	.0960	190
200	.1022	.1008	.0999	.0993	.0988	.0984	.0980	.0977	.0974	.0972	.0969	200
210	.1033	.1018	.1009	.1003	.0998	.0994	.0990	.0987	.0984	.0981	.0979	210
220		.1029	.1019	.1013	.1008	.1004	.1000	.0997	.0994	.0991	.0989	220
230		.1039	.1031	.1024	.1018	.1013	.1010	.1007	.1003	.1001	.0999	230
240		.1050	.1041	.1034	.1029	.1024	.1020	.1017	.1014	.1011	.1009	240
250		.1062	.1053	.1045	.1040	.1035	.1031	.1027	.1025	.1022	.1019	250

Table No. 171.

SIZE OF CHIMNEYS FOR STEAM BOILERS.

(Kent.)

HEIGHT OF CHIMNEYS AND COMMERCIAL—HORSE POWER.											Side of Sq. Ins.	Effective Area Sq. feet	Actual Area Sq. feet
50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.			
23	25	27	.....	.....	.....	.....	.....	.....	.....	.....	16	0.97	1.77
35	38	41	.....	.....	.....	.....	.....	.....	.....	.....	19	1.47	2.41
49	54	58	62	.....	.....	.....	.....	.....	.....	.....	22	2.08	3.14
65	72	78	83	.....	.....	.....	.....	.....	.....	.....	24	2.78	3.98
84	92	100	107	113	.....	.....	.....	.....	.....	.....	27	3.58	4.91
.....	115	125	133	141	.....	.....	.....	.....	.....	.....	30	4.48	5.94
.....	141	152	163	173	182	.....	.....	.....	.....	.....	32	5.47	7.07
.....	.....	183	196	208	219	.....	.....	.....	.....	.....	35	6.57	8.30
.....	.....	216	231	245	258	271	.....	.....	.....	.....	38	7.76	9.62
.....	.....	.....	311	330	348	365	389	.....	.....	.....	43	10.44	12.57
.....	.....	.....	.....	427	449	472	503	551	.....	.....	48	13.51	15.90
.....	.....	.....	.....	536	565	593	632	692	748	.....	54	16.98	19.64
.....	.....	.....	.....	.....	694	738	776	849	918	981	59	20.83	23.76
.....	.....	.....	.....	.....	835	876	934	1023	1105	1181	64	25.08	28.27
.....	.....	.....	.....	.....	.....	1038	1107	1212	1310	1400	70	29.73	33.18
.....	.....	.....	.....	.....	.....	1214	1294	1418	1531	1637	75	34.76	38.48
.....	.....	.....	.....	.....	.....	.....	1496	1639	1770	1893	80	40.19	44.18
.....	.....	.....	.....	.....	.....	.....	.....	1876	2027	2167	86	46.01	50.27

* Diameter in inches.

For lbs. of coal burned per hour for any given size of chim- multiply figures in the table by 5. On 2.5 lb basis, chimney ouble the actual horse power above given.

Table No. 172.

Properties of Saturated Steam.

Total pressure per square in.	Temperature in Fahrenheit Degrees.	Total heat in heat units from water at 32° F.	Latent heat in heat units.	Density or weight of 1 cubic foot.	Volume of one pound of steam.	Relative volume or cubic ft. of steam from 1 cubic foot of water	Factor of [illegible]
1	102.	1113.06	1042.964	0030	330.36	20620.	0.965
2	126.266	1120.45	1026.010	.0058	172 08	10720.	0.972
3	141.622	1125.131	1015.254	.0085	117.52	7326.	0.977
4	153 070	1128.625	1007.229	.0112	89.62	5600.	0.981
5	162.330	1131.449	1000.727	.0137	72.66	4535.	0.984
6	170.123	1133.826	995.249	.0163	61.21	3814.	0.986
7	176.910	1135.896	990.471	.0189	52.94	3300.	0.988
8	182.910	1137.726	986.245	.0214	46.69	2910.	0.990
9	188.316	1139.375	982 434	.0239	41.79	2607.	0.992
10	193.240	1140.877	978.958	.0264	31.84	2360.	0.994
15	213.025	1146.912	964.973	.0387	25.85	1612.	1.00[illegible]
20	227.917	1151.454	954 415	.0511	19.72	1220.3	1.00[illegible]
25	240.000	1155.139	945.825	.0634	18.99	984 8	1.008
30	250.245	1158.263	938.925	.0755	13.46	826.8	1.012
35	259.176	1160 987	932.152	.0875	11.65	713 4	1.015
40	267.120	1163.410	926.472	.0994	10.27	628.2	1.017
45	274.296	1165.600	921.334	.1111	9.18	561.8	[illegible]
50	280.854	1167.600	916.631	.1227	8.31	508.5	[illegible]
55	286 897	1169.442	912.290	.1343	7.61	464.7	[illegible]
60	292.520	1171.158	908.247	.1457	7.01	428.5	[illegible]
65	297.777	1172.762	904.462	.1569	6.49	397 7	[illegible]
70	302.718	1174.269	900.899	.1681	6.07	371.2	[illegible]
75	307.388	1175.692	897 526	.1792	5.68	348.3	[illegible]
80	311.812	1177.042	894.330	.1901	5.35	328.3	[illegible]
85	316.021	1178.326	891.286	.2010	5.05	310.5	[illegible]
90	320.039	1179.551	888.375	.2118	4.79	294.7	[illegible]
95	323.884	1180.724	885 588	.2224	4.55	280.6	[illegible]
100	327.571	1181.849	883.914	.2330	4.33	267.9	[illegible]
105	331.113	1182.929	880.342	.2434	4.14	265.5	[illegible]
110	334.523	1183.970	877.865	.2537	3.97	246.0	[illegible]
115	337.814	1184.974	875 472	.2640	3.80	236.3	[illegible]
120	340.995	1185.944	873.155	.2742	3.65	227.6	[illegible]
125	344.074	1186.883	870.911	.2842	3.51	219.7	[illegible]
130	347.059	1187.794	868.735	.2942	3.38	212.3	[illegible]
140	352.757	1189.535	864.566	.3138	3.16	199 0	[illegible]
150	358.161	1191.180	860.621	.3340	2.96	187.5	[illegible]
160	363.277	1192.741	856.874	.3520	2.79	177.3	[illegible]
170	368.158	1194.228	853 294	.3709	2.63	168.4	[illegible]
180	372.822	1195.650	849 869	.3889	2.49	160.4	[illegible]
190	377 291	1197 013	846.584	.4072	2.37	153.4	[illegible]
200	381.573	1198.319	843.432	.4249	2.26	147.1	[illegible]
250	401.072	1203.735	831.222	.5464	1 83	14.	[illegible]
300	418.225	1208.737.	819 610	.6486	1.54	96	[illegible]
350	431 956	1212 580	810.690	.7498	1.33	83.	[illegible]
400	444.919	1217 094	800.198	.8502	1.18	73.	[illegible]

Vapor at the instant of its formation is said to be saturated; it then contains all the heat in the water from which it was formed plus "the heat of vaporization." If pressure is now maintained constant and heat added the vapor will be superheated. If heat is applied to water at the boiling point, its temperature will not be increased, but the heat will be absorbed and perform work in transforming the water into steam. The heat thus absorbed is "heat of vaporization" above referred to.

Table No. 173.

HEAT UNITS IN WATER BETWEEN 32 AND 212 FAHR., (reckoned from 32 Fahr.) AND WEIGHT OF WATER PER CUBIC FEET.

Temperature.	Heat Units.	Weight lbs. per cub. foot.	Temperature.	Heat Units.	Weight lbs. per cub. foot.	Temperature.	Heat Units.	Weight lbs. per cub. foot.
32° F	0.	62.42	123° F	91.16	61.68	168° F	136.44	60.81
35	3	62.42	124	92.17	61.67	169	137.45	60.79
40	8	62.42	125	93.17	61.65	170	138.45	60.77
45	13.	62.42	126	94.17	61.63	171	139.46	60.75
50	18	62.41	127	95.18	61.61	172	140.47	60.73
52	20.	62.40	128	96.18	61.60	173	141.48	60.70
54	22.01	62.40	129	97.19	61.58	174	142.49	60.68
56	24.01	62.39	130	98.19	61.56	175	143.50	60.66
58	26.01	62.38	131	99.20	61.54	176	144.51	60.64
60	28.01	62.37	132	100.20	61.52	177	145.52	60.62
62	30.01	62.36	133	101.21	61.51	178	146.52	60.59
64	32.01	62.35	134	102.21	61.49	179	147.53	60.57
66	34.02	62.34	135	103.22	61.47	180	148.54	60.55
68	36.02	62.33	136	104.22	61.45	181	149.55	60.53
70	38.02	62.31	137	105.23	61.43	182	150.56	60.50
72	40.02	62.30	138	106.23	61.41	183	151.57	60.48
74	42.03	62.28	139	107.24	61.39	184	152.58	60.46
76	44.03	62.27	140	108.25	61.37	185	153.59	60.44
78	46.03	62.25	141	109.25	61.36	186	154.60	60.41
80	48.04	62.23	142	110.26	61.34	187	155.61	60.39
82	50.04	62.21	143	111.26	61.32	188	156.62	60.37
84	52.04	62.19	144	112.27	61.30	189	157.63	60.34
86	54.05	62.17	145	113.28	61.28	190	158.64	60.32
88	56.05	62.15	146	114.28	61.26	191	159.65	60.29
90	58.06	62.13	147	115.29	61.24	192	160.67	60.27
92	60.06	62.11	148	116.29	61.22	193	161.68	60.25
94	62.06	62.09	149	117.30	61.20	194	162.69	60.22
96	64.07	62.07	150	118.31	61.18	195	163.70	60.20
98	66.07	62.05	151	119.31	61.16	196	164.71	60.17
100	68.08	62.02	152	120.32	61.14	197	165.72	60.15
102	70.09	62.00	153	121.33	61.12	198	166.73	60.12
104	72.09	61.97	154	122.33	61.10	199	167.74	60.10
106	74.10	61.95	155	123.34	61.08	200	168.75	60.07
108	76.10	61.92	156	124.35	61.06	201	169.77	60.05
110	78.11	61.89	157	125.35	61.04	202	170.78	60.02
112	80.12	61.86	158	126.36	61.02	203	171.79	60.00
114	82.13	61.83	159	127.37	61.00	204	172.80	59.97
115	83.13	61.82	160	128.37	60.98	205	173.81	59.95
116	84.13	61.80	161	129.38	60.96	206	174.83	59.92
117	85.14	61.78	162	130.39	60.94	207	175.84	59.89
118	86.14	61.77	163	131.40	60.92	208	176.85	59.87
119	87.15	61.75	164	132.41	60.90	209	177.86	59.84
120	88.15	61.74	165	133.41	60.87	210	178.87	59.82
121	89.15	61.72	166	134.42	60.85	211	179.89	59.79
122	90.16	61.70	167	135.43	60.83	212	180.90	59.76

A cubic inch of water, evaporated under ordinary atmospheric pressure, is converted into 1,700 cubic inches, or, in round numbers, 1 cubic foot of steam, and gives a mechanical force equal to raising 2,200 pounds one foot high.

The specific gravity of steam (at atmospheric pressure) is .411 that of air at 34° Fahr.; .0006 that of water at same temperature. 27,222 cubic feet of steam weigh one pound; 13,817 cubic feet of air weigh one pound. Locomotives average a consumption of 3,000 *gallons of* water per 100 miles run.

Table No. 174.

[illegible] EQUIVALENT [illegible] 212 [illegible]

[illegible]	STEAM GAUGE PRESSURE							
	[illegible]	20	40	60	80	100	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] pounds of water [illegible] fuel [illegible] and called [illegible] economy [illegible] stated, this is [illegible] pounds of water evap[illegible] pressure. In calculating [illegible] heating surface is [illegible] horse-power.

[illegible] pounds of water [illegible] temperature [illegible] pressure [illegible] evaporation from

[illegible] table, find

Table No. 176.

Giving Mean Pressure of Steam at Different Rates of Expansion,

Initial Pressure in lbs. per sq. in.*	Average Pressure in lbs. per Square Inch for the Whole Stroke.							
	Points in the Stroke at Which Steam is Cut Off.							
	0.1	0.2	0.25	0.3	0.0375	0.4	0.5	0.6
40	13.21	20.87	23.86	26.22	29.67	30.66	33.86	36.14
45	14.86	23.48	26.84	29.73	33.38	34.89	38.09	40.66
50	16.51	26.09	29.82	33.03	37.07	38.32	42.32	45.18
55	18.12	28.57	32.86	36.67	40.83	42.08	46.47	49.91
60	19.79	31.02	35.77	39.23	44.49	45.98	50.73	54.41
65	21.49	33.84	38.71	42.98	48.35	49.89	54.98	58.96
70	23.18	36.43	41.73	46.22	52.00	53.52	59.07	63.25
75	24.72	39.00	44.82	49.53	55.73	57.36	63.38	68.00
80	26.41	41.66	47.75	52.88	59.41	61.13	67.47	72.45
85	28.02	44.08	50.65	56.14	63.17	65.00	71.84	77.00
90	29.69	46.89	53.73	59.43	66.94	68.83	76.00	81.47
95	31.34	49.37	56.62	62.81	70.52	72.68	80.16	86.00
100	33.03	52.00	59.63	66.01	74.23	76.47	84.37	90.57
110	36.41	57.46	65.87	72.97	81.82	84.12	93.00	99.95
120	39.77	62.50	71.48	79.44	89.10	91.98	101.44	108.63
130	43.01	67.85	77.49	86.00	96.55	99.47	110.00	117.89
140	46.32	73.00	83.38	92.51	104.00	107.21	118.36	126.77
150	49.73	78.11	89.12	99.04	111.63	114.56	126.89	136.00

"Initial pressure" in above table means Absolute Pressure; pressure reckoned from vacuum or guage pressure + 15 lbs. approximately

The average pressures given should have deducted from them a proper amount for "back pressure" or from 16 to 17 bs. for average non condensing engine, or to 7 lbs. for good condensing engine.

With no allowance for "banking fires" or ashes, with boiler and appurtenances adapted to the work, the best compound engines will run on 2 lbs. or even 1.75 lbs. of coal per hour per horse-power, day in and day ou' esign scientifically, and install best of Engines, Bo s, etc. See part 2.

Table No. 177.
STEAM ENGINES.

GIVING THE INDICATED HORSE POWER FOR EACH POUND MEAN EFFECTIVE PRESSURE, FOR VARIOUS DIAMETERS AND SPEEDS OF PISTONS.

Diameter Cylinder.	Speed of piston in feet a minute.									
"	240	300	350	400	450	500	550	600	650	700
10	.571	.714	.833	.952	1.071	1.168	1.309	1.428	1.243	[illegible]
11	.691	.864	1.008	1.152	1.296	1.44	1.584	1.725	1.872	[illegible]
12	.820	1.025	1.195	1.366	1.540	1.708	1.880	2.050	2.222	[illegible]
13	964	1.206	1.407	1.608	1.809	2.01	1.211	2.412	2.613	3.015
14	1.119	1.398	1.631	1.864	2.097	2.331	2.564	2.797	3.029	3.495
15	1.285	1.606	1.873	2.131	2.409	2.677	2.945	3.212	3.479	4.004
16	1.461	1.827	2.131	2.436	2.741	3.045	3.349	3.654	3.958	[illegible]
17	1.643	2.054	2.396	2.739	3.081	3.424	3.766	4.108	4.450	5.135
18	1.849	2.312	2.697	3.083	3.468	3.854	4.239	4.624	5.009	[illegible]
19	2.061	2.577	3.006	3.436	3.865	4.295	4.724	5.154	5.583	[illegible]
20	2.292	2.855	3.331	3.807	4.285	4.759	5.234	5.731	6.186	[illegible]
21	2.518	3.148	3.672	4.197	4.722	5.247	5.771	6.296	6.820	[illegible]
22	2.764	3.455	4.031	4.607	5.183	5.759	6.334	6.911	7.486	[illegible]
23	3.021	3.776	4.405	5.035	5.664	6.294	6.923	7.552	8.181	9.44
24	3.289	4.111	4.797	5.482	6.167	6.853	7.538	8.223	[illegible]	[illegible]
25	3.569	4.461	5.105	5.948	6.692	7.436	8.179	8.923	9.566	[illegible]
26	3.861	4.826	5.630	6.435	7.239	8.044	8.848	9.652	10.456	[illegible]
27	4.159	5.199	6.066	6.932	7.799	8.666	9.532	10.399	11.265	[illegible]
28	4.477	5.596	6.529	7.462	8.395	9.328	10.261	11.193	12.125	[illegible]
29	4.805	6.006	7.007	8.008	9.009	10.01	11.011	12.012	13.013	[illegible]
30	5.141	6.426	7.497	8.568	9.639	10.71	11.781	12.852	13.923	[illegible]
31	5.486	6.865	8.001	9.144	10.287	11.43	12.573	13.716	14.866	[illegible]
32	5.846	7.308	8.526	9.744	10.962	12.18	13.398	14.616	15.834	[illegible]
33	6.216	7.770	9.065	10.360	11.655	12.959	14.245	15.54	16.835	[illegible]
34	6.59	8.238	9.611	10.983	12.357	13.73	15.103	16.476	17.849	[illegible]
35	6.993	8.742	10.199	11.656	13.113	14.57	16.027	17.484	18.941	[illegible]
36	7.401	9.252	10.794	12.336	13.878	15.42	16.962	18.504	20.046	[illegible]
37	7.819	9.774	11.403	13.032	14.861	16.29	17.919	19.545	21.177	[illegible]
38	8.246	10.305	12.026	13.744	15.462	17.18	18.898	20.616	22.334	25.770
39	8.648	10.86	12.67	14.48	16.29	18.1	19.91	21.62	23.53	27.15
40	9.139	11.424	13.328	15.232	17.136	19.04	20.944	22.848	24.752	[illegible]
41	9.604	12.008	14.007	16.008	18.009	20.00	22.011	24.012	26.013	[illegible]
42	10.065	12.594	14.693	16.792	18.901	20.99	23.089	25.188	27.287	[illegible]
43	10.56	13.20	15.4	17.6	19.8	22.0	24.2	26.4	28.6	[illegible]
44	11.046	13.818	16.121	18.424	20.727	23.03	25.333	27.636	29.939	[illegible]
45	11.563	14.454	16.863	19.272	21.681	24.09	26.399	28.908	31.317	[illegible]
46	12.086	15.128	17.626	20.144	22.662	25.18	27.698	30.216	32.754	[illegible]
47	12.614	15.768	18.396	21.024	23.652	26.28	28.908	31.536	34.164	39.420
48	12.846	16.446	19.187	21.928	24.669	27.41	30.151	32.152	35.633	41.115
49	12.913	17.142	19.999	22.856	25.713	28.57	31.427	34.284	37.141	42.855
50	14.28	17.85	20.825	23.8	26.775	29.75	32.725	35.7	38.675	44.625
51	14.832	18.54	21.665	24.76	27.855	30.95	34.045	37.08	40.205	46.425
52	15.437	19.296	22.512	25.728	28.944	32.16	35.376	38.592	41.808	48.240
53	16.041	20.052	23.394	26.736	30.078	33.42	36.762	40.104	43.446	50.13
54	16.656	20.82	24.29	27.76	31.23	34.7	38.17	41.64	45.11	52.05
55	17.275	21.594	25.193	28.792	32.391	35.99	39.589	43.188	46.787	53.985
56	17.909	22.386	26.117	29.848	33.579	37.31	41.041	44.772	48.503	55.965
57	18.557	23.196	27.062	30.928	34.794	38.66	42.526	46.392	50.258	57.99
58	19.214	24.018	28.021	32.024	36.027	40.03	44.033	48.036	52.039	60.045
59	19.902	24.852	28.994	33.136	37.278	41.42	45.562	49.704	53.846	62.15
60	20.558	25.698	29.981	34.264	38.547	42.83	47.113	51.396	55.679	64.245

EXAMPLE, showing use of the two preceeding tables.

REQUIRED, the horse-power of a condensing engine, with 18" cylinder and piston speed of 500 ft. per minute, admitting steam at 80 lbs. guage pressure, and cutting off at ¼ stroke.

80 lbs. + 15 = 95 lbs. absolute pressure. In Table No. 176, opposite 95 lbs., and under ¼ (0.25) stroke find 56.62 lbs. Deducting say 5 lbs. for back pressure as mentioned under Table No. 176, we have 51.62 lbs. as the net mean effective pressure. In Table No. 177, opposite 18" cylinder, we find under 500 ft. piston speed, 3.854 horse power for each lb. mean effective pressure.

∴ we have, 3 584 × 51.62 = 185. horse power as the horse power of the engine under conditions given.

Table No. 179.

Amount of Feed Water in Pounds per Horse Power per Hour Required to Operate Steam Pumping Engines.*

Duty.	From Feed at 212° F. to Steam of:					From Feed at 100° F. to Steam of					Equivalent to Boiler Work in U. of E. in Pounds from and at 212° F.
	75 lbs.	100 lbs.	125 lbs.	150 lbs.	175 lbs.	75 lbs.	100 lbs.	125 lbs.	150 lbs.	175 lbs.	
110 Mill.	17.37	17.30	17.23	17.16	17.09	15 64	15.57	15.50	15 44	15.38	18.00
100 Mill.	19.11	19.03	18.95	18.87	18.80	17.20	17.12	17.05	16.98	16.92	19.80
90 Mill.	21.23	21.14	21.06	20.97	20.88	19.11	19.02	18.94	18.87	18.80	22.00
80 Mill.	23.90	23.80	23.70	23.60	23.50	21.50	21.40	21.31	21.22	21.15	24.75
70 Mill.	27.30	27.19	27.07	26.96	26.86	24.57	24.46	24.36	24.26	24.17	28.29
60 Mill.	31.85	31.71	31.58	31.45	31.33	28.67	28.53	28.42	28.30	28.20	33.00
50 Mill.	38.22	38.06	37.90	37.74	37.60	34.40	34.24	34.10	33.96	33.84	39.60

*Based on an evaporation of 10 lbs. of water from and at 212° Fahr. per lb. of coal.

Table No. 180.

Amount of Coal Required to Raise One Million Gallons of Water per 24 Hours, 200', the Corresponding Duty and Quantity of Fuel per Horse Power per Hour.

(Sherman.)

Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hourper H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.	Duty.	Lbs. Coal per Million Gallons.	Lbs. Coal per Hour per H. P.
30	5560	5.94	51	3271	3 49	71	2349	2 51	91	1833	1 96
31	5380	5.75	52	3208	3.43	72	2317	2 48	92	1813	1.94
32	5212	5.57	53	3147	3.36	73	2285	2.44	93	1793	1.92
33	5054	5.40	54	3089	3.30	74	2254	2.41	94	1774	1.90
34	4906	5.24	55	3033	3.24	75	2224	2.38	95	1756	1.88
35	4766	5.09	56	2979	3.18	76	2195	2.35	96	1738	1.86
36	4634	4 95	57	2926	3 13	77	2166	2.31	97	1720	1.84
37	4508	4.82	58	2876	3 07	78	2138	2.28	98	1702	1.82
38	4390	4.69	59	2827	3.02	79	2111	2.26	99	1685	1.80
39	4276	4.57	60	2780	2 97	80	2085	2.23	100	1668	1 78
40	4170	4.45	61	2734	2 92	81	2059	2.20	101	1651	1.76
41	4068	4.35	62	2690	2.87	82	2034	2.17	102	1635	1.75
42	3972	4.24	63	2648	2.83	83	2009	2.15	103	1619	1.73
43	3880	4.14	64	2606	2.78	84	1985	2 12	104	1604	1.71
44	3790	4.05	65	2566	2 74	85	1962	2 10	105	1589	1.70
45	3707	3.95	66	2527	2 70	86	1940	2 07	106	1573	1.68
46	3626	3.87	67	2490	2.66	87	1917	2.05	107	1559	1.67
47	3549	3.79	68	2453	2.62	88	1895	2.02	108	1544	1.65
48	3475	3.71	69	2417	2.58	89	1874	2.00	109	1530	1.63
49	3404	3.63	70	2383	2.55	90	1853	1.98	110	1516	1.62
50	3336	3.56	...	...	....	...	....	....	....	....	....

The above table assumes that 90 per cent. of power *applied* at "steam end" performs useful work at the "*water end*" of the pump.

High Pressure Cylinder	Cubic Feet in 12 Inches	Cubic Feet per Minute, Both Sides	INITIAL STEAM PRESSURE								
			50	60	70	80	90	100	110	120	130
10	.5455	109	1,005	1,160	1,300	1,440	1,580	1,720	1,860	2,000	2,150
11	.66	132	1,220	1,400	1,570	1,740	1,920	2,090	2,260	2,430	2,600
12	.7854	157	1,450	1,660	1,870	2,070	2,280	2,480	2,680	2,900	3,100
13	.9218	185	1,710	1,960	2,200	2,450	2,690	2,930	3,160	3,400	3,650
14	1.069	214	1,980	2,270	2,550	2,830	3,110	3,390	3,660	3,940	4,200
15	1.227	245	2,260	2,600	2,800	3,240	3,550	3,870	4,190	4,500	4,830
16	1.396	279	2,580	2,950	3,320	3,680	4,050	4,400	4,760	5,120	5,490
17	1.576	315	2,910	3,340	3,750	4,160	4,570	4,980	5,400	5,800	6,200
18	1.767	353	3,260	3,750	4,200	4,650	5,100	5,580	6,010	6,500	6,950
20	2.182	436	4,030	4,620	5,190	5,770	6,330	6,900	7,450	8,050	8,600
22	2.640	528	4,880	5,590	6,260	6,950	7,620	8,300	9,000	9,700	10,400
24	3.142	628	5,800	6,650	7,450	8,280	9,100	9,900	10,700	11,500	12,400
26	3.687	737	6,800	7,800	8,750	9,700	10,700	11,600	12,600	13,500	14,500
28	4.276	856	7,900	9,080	10,200	11,300	12,400	13,700	14,600	15,700	16,900
30	4.909	982	9,100	10,400	11,700	13,000	14,300	15,600	16,800	18,100	19,400
32	5.585	1,117	10,300	11,800	13,200	14,700	16,200	17,000	19,000	20,500	22,000
34	6.305	1,261	11,700	13,400	15,200	16,700	18,400	20,000	21,600	23,300	24,900
36	7.069	1,414	13,100	15,000	16,800	18,700	20,500	22,400	24,200	26,000	27,800
38	7.876	1,575	14,600	16,700	18,700	20,800	22,900	24,900	26,900	29,000	31,000
40	8.728	1,746	16,200	18,500	20,800	23,200	25,500	27,700	30,000	32,200	34,500

The amounts of steam in lbs. per hour given under each initial pressure opposite the several diameters of High Pressure cylinders are approximate only. The actual amount will depend on make of pump, leakage, etc. For ordinary duplex pumps, the actual consumption of steam is from 10 to 25 per cent. more than given, when due allowance is made for the above, condensation, auxiliary pumps, etc.

For necessary boiler horse power (centennial standard) divide amounts given by 30. For any other piston speed find by proportion

The following few tables are taken from the catalogues of some of the many Pump Manufacturers represented in Part 2, but not with the intention of indirectly saying "one make is better than another." The author presumes that many users of this work will at times be caught in public meeting or elsewhere, as he has been, without a bundle of catalogues in his pocket, and required to give at least an approximate yet prompt decision as to proper size of pump and connections; with the object of assisting at such times they are inserted.

Table No. 182.

COMPOUND STEAM PUMPS.

(H. R. Worthington).

Diameter of Steam Cylinders.	Diameter of Water Plungers.	Length of Stroke.	Displacement in Gallons per stroke of each Plunger.	Proper strokes per minute of each Plunger, varying with kind of work and pressure.	Gallons delivered per minute by both Plungers at stated number of strokes.	Diameter of Plunger required in any single cylinder pump to do the same work at same speed.	Sizes of Pipes for Short Lengths. To be increased as length increases. Steam Pipe.	Exhaust Pipe.	Suction Pipe.	Discharge Pipe.	Telegraphic Code Word.
8 & 12	7	10	1.66	75 to 125	245 to 410	9½	2	3	6	5	Apple
8 " 12	8½	10	2.45	75 " 125	365 " 610	12	2	3	6	5	Beet
10 " 16	8½	10	2.45	75 " 125	365 " 610	12	2	3	6	5	Cherry
12 " 18½	8½	10	2.45	75 " 125	365 " 610	12	2½	3½	6	5	Apricot
14 " 20	8½	10	2.45	75 " 125	365 " 610	12	2½	5	6	5	Tomato
8 " 12	10¼	10	3.57	75 " 125	530 " 890	14½	2	3	8	7	Plum
10 " 16	10¼	10	3.57	75 " 125	530 " 890	14½	2	3	8	7	Grape
12 " 18½	10¼	10	3.57	75 " 125	530 " 890	14½	2½	3½	8	7	Melon
14 " 20	10¼	10	3.57	75 " 125	530 " 890	14½	2½	5	8	7	Prune
8 " 12	12	10	4.89	75 " 125	730 " 1220	17	2	3	10	8	Orange
10 " 16	12	10	4.89	75 " 125	730 " 1220	17	2	3	10	8	Gooseberry
12 " 18½	12	10	4.89	75 " 125	730 " 1220	17	2½	3½	10	8	Quince
14 " 20	12	10	4.89	75 " 125	730 " 1220	17	2½	5	10	8	Strawberry
10 " 16	14	10	6.66	75 " 125	990 " 1660	19½	2	3	12	10	Banana
12 " 18½	14	10	6.66	75 " 125	990 " 1660	19½	2½	3½	12	10	Peach
14 " 20	14	10	6.66	75 " 125	990 " 1660	19½	2½	5	12	10	Mulberry
12 " 17	10	15	5.10	50 " 100	510 " 1020	14	2½	3½	8	7	Blackberry
14 " 20	10	15	5.10	50 " 100	510 " 1020	14	2½	5	8	7	Lemon
12 " 17	11	15	6.20	50 " 100	620 " 1240	15½	2½	3½	10	8	Coladin
14 " 20	11	15	6.20	50 " 100	620 " 1240	15½	2½	5	10	8	Coladot
14 " 20	12	15	7.34	50 " 100	730 " 1460	17	2½	5	12	10	Olive
12 " 17	15	15	11.47	50 " 100	1145 " 2290	21					Tangerine
14 " 20	15	15	11.47	50 " 100	1145 " 2290	21					Mango
16 " 25	15	15	11.47	50 " 100	1145 " 2290	21					Guava
14 " 20	17	15	14.74	50 " 100	1470 " 2940	24					Lime
18½ " 29	16	18	15.66	40 " 75	1250 " 2345	22½					Pear

Many other sizes and combinations are also made.

An average compound steam pumping plant can be run with about two-thirds the coal required to perform the same work, with same boilers and connections, by an average single cylinder or high pressure form of pump.

When interest on investment, maintainence, etc. are properly considered, it does not always pay with small plant, say under two million capacity, to provide for compound condensing outfit. With large capacity, the cases are few where it does not pay to so provide.

For cut of compound pump, see page 13, part 2.

Table No. 183.

General Service Triplex Pump.

(The Deming Co.)

Single Acting Pattern.

...oke	Gallons per Revolution	Revolutions per Minute	Gallons per Minute	Piping Suction	Piping Discharge	Gear Ratio	Pulleys	Cipher
in.	.081	60	4.8	1¼ in.	1 in.	5 to 1	8x 2	Obese
"	127	60	7.6	1½ "	1 "	5 " 1	10x 2	Obelize
"	.19	60	11	2 "	1¼ "	5 " 1	12x 3	Oaken
"	.27	60	16	2 "	1¼ "	5 " 1	14x 3	Oath
"	.37	60	22	2 "	1¼ "	5 " 1	16x 3	Oakling
"	.50	60	30	2½ "	2 "	5 " 1	16x 4	Obelus
"	.65	60	39	2½ "	2 "	5 " 1	18x 4	Oakum
"	.98	60	59	2½ "	2 "	5 " 1	20x 5	Oarsman
"	1.53	60	91	3 "	2½ "	5 " 1	24x 5	Oasis
"	2.46	60	147	4 "	3 "	5 " 1	28x 6	Oatmeal
"	4.00	45 to 60	240	5 "	4 "	5 " 1	30x 8	Obdurate
"	5.90	45 " 60	354	5 "	4 "	5 " 1	36x 8	Obdure
"	8.26	35 " 50	413	8 "	6 "	5 " 1	42x10	Obloquy
"	10.20	35 " 50	510	8 "	6 "	5 " 1	44x12	Obsignate

Double Acting Pattern.

...roke	Gallons per Revolution	Revolutions per Minute	Gallons per Minute	Piping Suction	Piping Discharge	Gear Ratio	Pulleys	Cipher
in.	7.75	45 to 60	465	8 in.	6 in.	5 to 1	Special	Obeisance
"	11.54	45 " 60	692	8 "	6 "	5 " 1	"	Obedient
"	16.08	35 " 50	804	10 "	8 "	5 " 1	"	Obtrude
"	19.76	35 " 50	988	10 "	8 "	5 " 1	"	Ocherous

apacities given are for Maximum Speeds.

above style of pump (belted) can often be used ations quite inaccessible for economic steam de-; can be belted to and operated by electric motor, direct or alternating current or can be belted to in turn operated by any available power.

en water works and Electric plant are under same gement. pump can balance fluctuations in electric thus increasing the efficiency of plant as a whole. ch cases it is best to have two or three pumps of capacity, rather than in one unit and have them cted with "cut out couplings" so that one or all pumps can be started and operated without stop- the electric machines. Such pumps, operated by id oil engines, electric motor, etc., are much used olated service where constant attention cannot be

ut of Triplex see Part 2, page 16.

Centrifugal Pumps.

circulating water through surface condensers, ing out excavations, coffer-dams, etc., in irriga- ifting sewage or water at filter-beds, in excavating, lt. sand, gravel, etc., where ample supply of water

[illegible]

ons in deciding on size of pump to use assume square f diameter of suction equals discharge of pump in cu. ft. per hour.

Table No. 185

SINGLE SIDE SUCTION PUMPS, WITH "DIRECT CONNECTED" VERTICAL ENGINE. (Same bed plate.) ....
(The Lawrence Machine Co.)

No. of Pump.	Size of Pipe.		Size of Engine Cylinder.		Capacity in Gal'ns per Minute.	Greatest Height for which Recommended.	Total Weight
	Suction.	Disch'rge	Diameter.	Stroke.			
No. 3	6	3	4"	4"	180	20'	900
" 4	8	4	4	4	300	25	1000
" 5	8	5	4	4	500	25	1100
" 6	10	6	6	6	800	25	1600
" 8	10	8	6	6	1300	15	1800
" 8	10	8	7	7	1300	25	2000
" 10	12	10	7	7	2200	18	2300
" 10	12	10	8	8	2500	25	3500
" 12	14	12	8	8	3000	18	4000

CHIMNEYS AND STACKS

Should be higher than surrounding or near by buildings or hills, otherwise wind from the direction of them impair the efficiency of draft.

For combustion in, air required, fuel, etc., see Tables Nos. 146 to 150 inclusive.

Table No. 171 gives the diameter and height of chimneys for a given horse power; it is based on a coal consumption of 5 lbs. per horse power hour or an evaporation of 7 lbs. of water per lb. of coal.

It is not safe to assume less than 5 lbs. of coal per horse power hour for small inefficient plants; draft is often checked in such plants by long passage with bends before reaching the stack, while the thin metal of it, tends to quickly allow chilling of the contained gases, thus increasing their weight per unit of volume and materially reducing the velocity of their exit.

Many modern efficient plants, with good brick chimney use less than 2.5 lbs. of coal per horse power hour; for such plants chimneys will answer for double the horse power given in the table; for any other coal basis, the horse power can be quickly found by proportion.

[illegible] generally measured by its equivalent pressure in inches of water [illegible] and depends on the difference in weight between the gases in flue, chimney, etc., and an equivalent column in cross section and height of outside air.

Table No. [illegible]

[illegible] in Inches of Water with [illegible] Equivalents.

Inches of water [illegible]	Pounds per square foot	Ounces per square inch.
[illegible]	[illegible]	0.0577
[illegible]	[illegible]	0.1154
[illegible]	[illegible]	0.1731
[illegible]	[illegible]	0.2308
[illegible]	[illegible]	0.2885
[illegible]	[illegible]	0.577
[illegible]	[illegible]	1.154
[illegible]	[illegible]	1.731
[illegible]	[illegible]	2.308
[illegible]	[illegible]	2.885

[illegible] are a mixture of carbonic acid gas, [illegible] nitrogen, [illegible] and gaseous [illegible] As the amount of [illegible] is shown in Steam and [illegible] with the same chimney and temperature [illegible]

[illegible] shown that a chimney or stack large [illegible] small height can be equivalent to [illegible] great height; practically, however, there seems to be a height of stack varying with the [illegible] at which it is most economically burned [illegible] given the following table.

Table No. 187

[illegible] Chimneys to Burn Various Coals Economically.

Free burning Bituminous.	70 to 100 feet.
Slow burning Bituminous.	100 to 120 feet.
Bituminous Slack.	100 ft. or more.
Average Anthracite.	125 to 150 feet.
Anthracite Pea.	125 ft. or more.
Anthracite Buckwheat.	150 ft. or more.

.ong flues reduce chimney draft about 10 per cent. 100 ft. of flue within the limits of practice, counted m grate to chimney.

)ownward flow of gases, being in a direction oppo- : to that caused naturally should be avoided unless advantage gained compensates for the loss in draft :ssure.

CIRCULAR CHIMNEYS.

Have the outside diameter at the bottom about one ith the height and batter from three-tenths to one arter inch per foot.

With less than 5 ft. top internal diameter, thickness brick work at top should be one brick and increase e brick in thickness for every 30 to 36 ft. toward :tom. If greater than 5 ft. in top diameter, make ckness one and one half brick with same increase as st given toward bottom.

For wind strains use rules given under Stand Pipes, ge 260.

OCTAGON AND HEXAGON CHIMNEYS.

As a rule, on account of the greater amount of brick : cu. yd. of finished work (less mortar) in an octa- n or hexagon chimney, the wind strain is better re- ted by the octagon or hexagon chimney than by the cular. By using special corner brick, all work for : masons is "straight" and the cost per cu. yd. laid generally less than for circular chimney.

SQUARE CHIMNEYS.

If a square chimney is to be constructed, place it so it one diagonal line of the square will be in the direc- n of "prevailing winds;" this will increase its stability time of gale or cyclone over what it would be if wind essure was at right angles to one face or side.

PYROMETER TESTS.

The average temperature of the gases escaping to e chimney should be taken frequently or at least once r month when plant is running under "every day" orking conditions; tests should be made at least once r hour during the days run.

BOILERS

Should be safe, durable and efficient. Plates thicker an one-half inch should not be used where exposed to e *oxidizing or burning* action of fire, for if they are

of greatest thickness, the contained water ceases to act as a protection.

Each cu. ft. of contained hot water under 100 lbs. pressure contains more energy, if suddenly released, than a pound of dynamite; it is of the greatest importance that safety is therefore, made the first consideration when selecting a boiler. No boiler is safe, however, in the hands of inexperienced persons. As a general proposition, the water tube boiler is safest because and easily detected and remedied leak in tube or header effects but a portion of the stored energy; water tube boilers have, however, exploded and caused serious loss of life and property. On account of limiting thickness of metal, return tubular boilers are seldom made to carry over 150 lbs. pressure, internally fired boilers, 180 to 200, while the small diam. of tubes permit safe working pressures of 200, 300 and in exceptional cases as high as 500 lbs. pressure with the water tube type.

For boiler shell, open hearth steel or wrought iron is best; the average tensile strength of material used in ordinary practice is from 40,000 to 60,000 lbs. sq. in. of section. It will, when good, stand bending back on to itself without rupture when cold.

Double riveted boilers are about 1.25 times as strong as single riveted ones, hence can be about one fifth thinner. Lap welded boilers are about 1.75 times as strong as single riveted boilers and can be made of material

WORKING PRESSURE.

f boilers are in "battery" the working pressure should er exceed that of the safe pressure for weakest er; all safety valves should be set to blow-off at this ssure. If one of the boilers is much weaker than others, either arrange to "cut it out," using it for ie auxiliary service, or replace it by a new good :. A poor man in a "gang," horse in a team, or ler in a battery, set the pace for the others and do ' PAY.

SAFETY VALVE.

:ach boiler should have a safety valve of ample size :ctly connected. For 100 h. p., not less than 4 inch re should be used, other sizes in proportion. Test h safety valve every day.

PRESSURE GAUGE, ETC.

:ach boiler should have pressure gauge tested by able standard at least every month or six weeks. not depend on glass gauge for water level but use ge cocks also; never carry less than 5 or 6 inches of er above the flues at highest end. Keep gauge ks, glass gauge, water column and connections clean; w out glass gauge, and water column two or three es per day.

CAPACITY OF BOILERS.

See note under Table No. 174.

n 1876 when the American Society of Mechanical gineers adopted the Centenial Standard of 30 lbs. of er evaporated per hour from a feed water tempera- e of 100 deg. Fahr. at 70 lbs. pressure (as given ler table No. 174) as equivalent to a horse power or 00 foot-pounds, the average pressure carried was ch less than 100 lbs. To-day many compound con- ısing engines are running under more than 150 lbs. ssure. In 1876 it took, in the majority of cases re than 30 lbs. of water per h. p. hour; now the best ;ines are running on an average of perhaps slightly r one-half as much or say from less than 15 to more n 20 lbs. and this amount includes that required to rate necessary auxiliary apparatus such as water : air pumps.

HEATING SURFACE.

See Table No. 175.

calculating the horse power of boilers allow a

[illegible] square fe[illegible]

[illegible] considered a [illegible] boiler [illegible] horse po[illegible] surface; su[illegible] horse power [illegible] economy is a [illegible] surface [illegible] [illegible]

[illegible] Tests

[illegible] should be [illegible] determine the [illegible]

[illegible]

[illegible] the quality of coal [illegible] hard coal or [illegible] consumed per hour on [illegible] average boiler furnace, wi[illegible] from near[illegible] amount, depending on their [illegible] consumption [illegible] other governing [illegible]

34.8 equals 4350 lbs. of water per hour for 125 h. p. ler; this divided by 8.407 gives 517 lbs. of coal per ır. If 12 lbs. of coal are burned per sq. ft. of grate hour, we have 43 sq. ft. of grate surface, or say sq. ft. as necessary to run the above boiler on above .l under assumptions taken. This area should be perly proportioned to the boiler, limiting its depth to m 6 to 7 ft. to insure efficient firing.

Coals high in carbon, non-caking, require grate with all openings and a high stack, see table No. 187, so to create a high draft pressure to force air through all spaces in the coal bed.

Highly volatile, caking, coals require grate with large enings and ample cross-section of flue and stack.

It is evident that a grate surface of proper design d area for one kind of coal, will not be efficient with ners. If plant is constructed, it is well to try from ne to time a car load of various coals, and if a good eman is in charge, he will soon tell which is best to e.

Tests should be frequently made, 1st to determine e comparative value of the fuel used; 2nd to determine the amount of unconsumed fuel remaining in the shes. The first in a measure will check the fireman's pinion, while if the coal companies know you are making such tests, they will be more apt not to be "careless" n filling your order. The second will assist in deciding whether the grate bars and fuel are adapted one to the other.

In horizontal tubular boilers grate for best effect should be from 2.5 to 3. feet from boiler and there should be about 30 feet of grate surface for each 5 ft. x 16 feet of boiler.

Air Leaks.

Fill all crevices around connections, doors, cracks, etc. Unless you wish to waste coal, all air must enter through the fire.

Steam Leaks.

800 drops per minute (see page 253), amounts to a barrel per day or over 7,000 cu. inches. To waste this from steam pipes means a waste of the fuel necessary to make 7,000 cu. ft. of steam (see page 281), yet how often does the careless engineer or fireman permit it, *especially on public* works, and blame the boiler for

WATER

convenient
the water
will facilitate

increase the

reduces

the water

temper

gases

will be

therefore

the gases

temperature

water

the

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If of proper design, they will save from 10 to 15 per cent. of cost for fuel in most cases, while in others actual tests have shown a saving of over 20 per cent. From this should be deducted interest on the cost of the heater plus cost to maintain. Two of the most important advantages of heating feed water that cannot be accurately reduced to a money value are, 1st., Their use prolongs the life of the boiler by reducing the variation in temperature to a minimum, thus preventing excessive expansion and contraction. 2nd, Heating feed water as explained under "Boiler Waters" and as given in Table No. 196 tends to remove by precipitation and otherwise much mineral and other matter, oil, etc., from the water before it is delivered to the boilers.

Feed water heaters can be used to advantage between cylinder and air pump in condensing engines.

Feed Pump

Should run continuously and at a nearly uniform rate; two pumps running alternately are preferable for larger sizes of boilers; have feed pipe of ample size and not less than 2 inch for 100 h. p. boiler; other sizes in proportion. If feed water is heated above 212 deg. Fahr. by Economizer or otherwise, feed pipes should be increased in size in proportion to increaseed temperature.

Water, Steam, Evaporation, etc.

See Tables No.'s 168, 172, etc.

The best boilers, when properly set and fired, will evaporate from 7 to more than 10 pounds of water per pound of first-class coal.

As explained on page 280, if heat be applied to water at the boiling point, its temperature will not be increased but the heat will be absorbed in performing work in transforming the water into steam. Steam at this instant is called SATURATED or DRY steam provided it is free of entrained waters.

Table No. 189

Unit Measures of Water With Equivalents.

1 cubic foot of water equals	62.3791	lbs.
1 cubic inch of water equals	.03612	lbs.
1 gallon of water equals	8.338	lbs.
1 gallon of water equals	231.	cu. in.
1 cubic foot of water equals	7.476	gallons.
1 pound of water equals	27.7	cu. in.

The above data are calculated for distilled water at 62 degrees Fahr.

P equals pressure in lbs. per sq. in. P equals H x .434
H equals head of water in feet. H equals P x 2.307
Pressure per square foot equals H x 62.425

MEAN PRESSURE OF THE ATMOSPHERE is estimated at 14.7 lbs. per square inch. With a perfect vacuum, at sea level, it will therefore sustain a column of mercury 29.9 inches or a column of water 33.9 feet high.

ENTRAINED WATER.

In the mountains with light air (low barometric pressure) the moisture carried by the air is generally less than at the sea shore with high barometric pressure and close contact with larger proportion of water surface.

Often a slight current of air will not raise a dust, while a heavy wind will pick up and carry much of it. Likewise in a boiler, slow evaporation; large ratio between grate and heating surface; ample drum, dome or other space for the steam; low boiler pressure and other causes reduce the amount of water carried along mechanically by the steam at the instant of its formation. The water so carried is called ENTRAINED WATER, and steam containing a measurable percentage of it

Condensation in Pipes.

(See also page 307.)

Those familiar with steam or hot water heating real- the necessity of properly covering steam pipes in ler to reduce condensation of the enclosed flowing eam of steam to a minimum. In the ordinary ex- sed location of such steam pipes from boiler to engine steam pump, condensation is often as high as 0.5 1 pound per sq. ft. of exposed uncovered pipe per ur. Fair covering will reduce this at least one-half to 0.25 to 0.5 pound per sq. ft. per hour, where :am is not superheated, while the best of covering ll do even far better work, depending on exposure.

Superheating.

To superheat means to add heat to a steam beyond at due to pressure as explained on page 280. It tends evaporate entrained water. Numerous experiments iow that within practical limits, the gain in work per- rmed by using a superheated steam over DRY STEAM verages about 1 per cent. for each 7 or 8 degrees of uperheat.

70 to 80 degrees (Fahr.) superheat would therefore ncrease the work that could be performed about 10 per cent. over dry steam or about 12 to 15 per cent. over fair average "commercial steam." If superheating is carried to a point sufficient to evaporate the entrained water and to prevent condensation in the steam pipe, dry steam will be delivered to and INITIAL condensation reduced or prevented in the cylinder. This results in a decided advantage in reducing "engine waste;" increases the amount of net work performed; reduces liability of "blown out cylinder heads" especially in the many modern plants where "clearance space" is reduced to the lowest possible minimum consistent with safety. In special lines, superheating is a positive necessity and often the special apparatus is costly and expensive to operate and maintain.

Certain modern boilers are so constructed as to superheat, by waste gases on their way to the stack, from 20 to 30 or more degrees; often this amount is sufficient to provide for the advantages above mentioned, especially *if steam pipe to* engine or pump is short.

Separators and Receivers.

Introduced in the line of steam pipe close to the er

gine tend to prevent initial condensation in the cylinder by the delivery of a dry steam to it; they are also used with success between cylinders of compound or compound condensing engines. If of good design with proper diverging plates or so arranged as to depend on centrifugal force, the contained water is separated from the steam. Their use in connection with ample size RECEIVER is preferable; especially when rate of expansion in cylinder is high or where steam pipe is long or of too small rather than too large diameter.

Assuming average engine to "cut-off" at one-fourth stroke it is evident that the velocity of steam through the supply pipe during "period of admission" will be four times as great, when a receiver is not used, as the nearly constant velocity that can be maintained when one is used. In other words a velocity of 100 ft. per second during period of admission can be reduced to the reasonable velocity of about 25 ft. per second. A receiver therefore tends to "keep up" the head and pressure of steam at the cylinder, reduces friction in pipe lines, and to a minimum, the effects of engine pulsation.

When steam is properly superheated, dry steam WILL be delivered to the engine and a separator is not necessary; often, however, they will do the work of separation for less money than it would take to prevent the necessity of separation by efficient superheating; again their use, even when steam is superheated tends to insure the removal of steam pipe condensation water at times when the degree of superheat may not be sufficient to prevent its formation.

Steam Drum and Trap

Differ little in work performed from Separator and Receiver.

STEAM ENGINES, ETC.

Horse Power of Steam Engines.

The indicated horse power of a steam engine for each pound mean effective pressure (m. e. p.) equals (area of piston in sq. inches x speed of piston in feet per minute) divided by 33,000. This quotient multiplied by (m. e. p.) equals the indicated horse power.

The above quotient multiplied b the average pressure equals the NOMINAL HORSE POWER.

The ACTUAL HORSE POWER is the indicated horse p

less power expended in overcoming friction; or indicated h. p. less 10 to 15 per cent. of total power in most cases.

Tables No.'s 176 and 177 are so arranged as to give the horse power of engines with cylinders varying from 10 to 60 inches in diameter, when steam is cut-off at different points of stroke with engine running at several different piston speeds; see example under table No. 177. EXAMPLE showing application of above rule to smaller engines than those given in Table No. 177.

REQUIRED, The horse power of a single cylinder non-condensing engine with 4 inch cylinder, cutting-off at one-fourth stroke and running at piston speed of 500 ft. per minute, under 85 lbs. gauge pressure. Area of piston by Table No. 54 equals 12.566 sq. inches; by above rule we have (12.566 x 500) divided by 33,000 equals 0.19 horse power for each pound mean effective pressure; adding to 85 lbs. gauge pressure, 15 lbs. to obtain the absolute pressure as given on under Table No. 176 we have 100 lbs. as the absolute initial pressure. In table No. 176 opposite 100 lbs. in the first column, find under one-quarter (0.25) stroke, 59.63 lbs. as the average pressure throughout the stroke; deducting 17 lbs. for back pressure (it may be more) for non-condensing engine as mentioned under Table No. 176 and we have 42.63 lbs. as the NET mean effective pressure; therefore by above rule we have 42.63 x 0.19 h. p. equals 8.09 horse power (Indicated). Deducting 10 per cent. for friction we have 7.29 horse power as the NET OR ACTUAL HORSE POWER under the conditions given.

TO FIND THE DIAMETER OF A CYLINDER of any engine of a required nominal horse power:

RULE.—Divide 5,500 by the velocity of the piston in feet per minute, and multiply the quotient by the required horse power, the product will be the area of piston in square inches; from this the diameter can be obtained by referring to tables No.'s 52 to 54 B.

TO FIND THE EFFECTIVE POWER OF AN ENGINE BY AN INDICATOR:

RULE.—Multiply the area of the piston in square inches by the average force of the steam in pounds; multiply this *product* by the velocity of the piston in *feet per minute; divide* this last product by 33,000, and *7-10 of the quotient* will be the effective power.

travel in feet of a piston is found by multiplying the distance it travels in inches per one stroke by the whole number of strokes per minute; dividing this product by 12 gives the number of feet the piston travels per minute.

A hundred pages could be here inserted relative to the action of steam in a cylinder; other rules, tables, multipliers, etc., may give slightly different results, but the above will cover all cases near enough for practical purposes, especially when the point of cut-off in the average engine considered would not be known within several hundredths or possibly a tenth, and where there are always so many outside factors to "upset" refined calculations. The Expert in such cases generally has to make from one to a dozen assumptions before he signs his name to a report, interesting though it may be in its array of figures, the practical every day man has not the time to digest them; he wants to know "what she will do;" "what will it cost in coal to run her, everything considered."

CUT-OFF.

The best point of cut-off in the average engine can generally be determined by dividing 2.5 by the square root of the initial pressure. For condensing engines figure pressure from vacuum; for non-condensing, from atmosphere.

Non-condensing engines are seldom running economical if point of cut-off is earlier than one-fourth stroke, when steam pressure is less than 100 lbs.

Cutting off earlier increases cylinder condensation. Cutting off later means increase in exhaust pressure to the point where useful foot-pounds of work are wasted by delivery into the atmosphere; if they must be so wasted make them heat feed water or perform some other duty.

SLIDE VALVE.

STROKE OF, equals 2 x lap plus 2 x width of steam port. One-half the "throw" of valve should at least equal the lap on the steam side plus breadth of port; if breadth is not sufficient to give the required area, increase throw of the valve.

LAP OF.—For any given point of cut-off.

Outside lap means "steam lap;" inside lap means exhaust lap.

Divide length of stroke after cut-off by total length of stroke; find square root of the remainder (use tables No. 46, etc.) Multiply the square root found by one-half the throw of valve and then subtract one-half the lead of the valve and the remainder equals lap required.

Increase throw of eccentric when lap is increased. Lap on steam side must always be greater than on exhaust side: the difference between lap on the two sides should increase as piston speed increases. In fast running engines exhaust valve should open in ample time for proper escape of steam.

Expansion by lap with slide valve operated by eccentric alone, ought not to exceed 0.3 stroke; if greater, in most cases, efficient operation is checked.

How to Set Slide Valve.

Place crank at centre with eccentric at right angles with crank; place valve in centre of its line of travel, with rocker at angle of 90 degrees with both cylinder and crank pin; next adjust valve gear to its proper length and move eccentric ahead until valve has lead desired; fasten eccentric and turn crank to other centre; if lead is equalized engine will run properly.

The chances are more than even that it will not be. Move eccentric back and ahead until it is. If lead is unequal on account of wear, take it up with brass or tin behind or in front of box connecting rocker and valve rod.

TYPES OF ENGINES

When outside factors do not limit your choice, remember when selecting an engine that,

1st. The cost of a net horse power decreases as the pressure increases.

2nd. The cost of a net horse power increases as the measure of expansion is increased beyond the point of minimum cost.

3rd. When measure of expansion in decreased below the point of minimum cost, the cost of a net horse power is increased but not as rapidly as in case just above given.

Whether plant be Compound Condensing, single cylinder *non-condensing* or otherwise, the greatest econom*is obtained when* "load" is nearly if not quite unifor *Hence the reason* why many direct pumping w

works systems cost much more to operate than exact duplicate of plant, but pumping to standpipe; in the first case pump must respond to each fluctuation in demand to a greater or less degree, while standpipe provides for it.

It also accounts for many electric plants being able to operate for less money with inefficient non-condensing engines with one engine for each one or two machines, than when same machines are all connected and driven by one large engine of high efficiency not properly arranged with sufficient cut-out couplings, etc.

Like the horse, see page 172, an engine must be adapted to the work to be performed or efficiency of plant as a whole will be low, no matter how great the efficiency of engine or the separate efficiency of machines run by it. The author recently made an examination of a 5,000 h. p. plant, where thousands of dollars had been expended for every conceivable modern engine and boiler appliance, but because of not being adapted to the work, Stokers and everything down the line to Cooling tower, did not help an efficient engine overcome neglect on the part of the designer of adapting plant to the load, thus resulting in a 3.25 lbs. coal consumption per h. p. hour; a consumption that would not have been exceeded by a properly designed single cylinder engine plant, costing not over one-fourth the money, but not quite as pretty to "look at." It is such neglect so often seen that prompted the remarks on page 240, under Steam and Fuel Notes.

Quality of Steam.

"Calorimeter tests" should be made from time to time to determine the amount of moisture; they show "effect" often of a cause that would not otherwise be detected; always use DRY or superheated steam as before mentioned.

Expansion.

Wide ratios of expansion are, other things being equal, conducive to economy.

In compound condensing plant with initial pressure (gauge) at or slightly above 100 lbs. and ratio of about *10 to 1* between it and release pressure the relative *areas* of cylinders ought to be from 3 to 3.3 to 1, with *proper* measure or amount of expansion; as pressure

:eased ratio of areas within limits can increase in portion.

'or compound non-condensing plant, under like conons, make ratio of capacities or areas from 2.8 to 3.1 1.

n a single cylinder, expansion of steam is practically ited to from 4 or 5 to 1, on account of the heavy s from condensation due to great difference in temature; compounding divides the change, reduces the ount of change in temperature in one cylinder and ults in a practical gain in work of the steam of about per cent., average over single cylinder condensing ;ine. The gain in running compound condensing :r single cylinder non-condensing will average more n double the above or more than 30 per cent.

CYLINDER CONDENSATION.

\n indicator does not register steam lost in condenion, leaks, etc. With good engines the amount lost condensation will vary with type and make of engine, 'ering, exposure, etc., but in per cent. of indicated am consumption will amount to from one eighth to : sixth x the square root of the ratio of expansion; s should be added to indicated consumption.

'Ratio of expansion" equals initial pressure divided release pressure.

CONDENSATION IN STEAM PIPES.

See also page 300.

[n winter condensation of steam is frequently as high one pound per sq. ft. per hour in exposed uncovered e lines; the best of covering will reduce the amount m 75 to 90 per cent.; poor covering from 25 to 50 r cent.

In summer or in rooms kept at summer temperature e amounts will not as a rule exceed over one-half ose given above.

Condensation water in pipe lines, delivered to and ising havoc in engine cylinder, is often attributed to a riming boiler" when as a matter of fact the boiler y be doing good work delivering dry steam. Erect es so that they will properly drain to receiver or er point where water can be removed.

CONDENSERS.

Vhen steam is exhausted into the atmosphere there is *ck pressure* due to its weight or at sea level about

... lbs. per sq. in. Condenser and air pump removes part of this back pressure; removing it amounts to the same thing as adding an equivalent amount to the steam pressure and exhausting into the atmosphere.

Jet Condenser.

Steam from engine cylinder discharges into a closed vessel into a spray or shower of cold water resulting in condensing each cu. ft. of steam into nearly its original volume of water or one cu. inch. (See under Table No. ...). This reduction in volume causes partial vacuum. If the entering steam and water did not carry a percentage of air and all connections and pipe lines were "air tight" and the condensing water was sufficient in amount not to be heated by the incoming steam, the vacuum would be perfect; these conditions are not practical and in the average good condenser there remains a back pressure of from 3 to 5 inches of mercury; as the weight of the atmosphere is balanced by a column of mercury approximately at sea level, of 30 inches high the vacuum gauge with fair condenser will stand at from 25 to 27 inches.

Air Pump.

The condensing water being heated by the incoming steam, causes "vapor of tension;" this with the air from the steam and water, and heated water are withdrawn by the air pump; if not so withdrawn, their accumulation would soon prevent space for partial vacuum.

Hot Well.

In condensing plants, feed water is generally taken from the hot well into which water of jet condenser is discharged. The advantages of high temperature of feed water have been before mentioned. It is best therefore even at expense of loss of "one or two inches" of vacuum to use but reasonable quantity of water for condensation, in order that water can be delivered hot to the feed water heater and thence to the boiler; the relation of "inches of vacuum" to temperature of w... given in following table.

Table No. 190

ΤIAL VACUUM AND CORRESPONDING TEMPERATURE OF WATER.

Inches of Mercury.	Temp. of water in Degrees Fahr.
0.	212
11	190
18	170
22.5	150
25	135
27.5	112
28.5	92
29	72

INJECTION WATER, AMOUNT OF.

The greater the efficiency of the engine, the greater e amount of the heat units absorbed from the steam; erefore as efficiency of engine is increased the work quired of the condenser is decreased, for it simply moves part of the heat units remaining in the exhaust eam from the engine; that is the injection water re-uces the temperature of the steam by increasing its wn temperature by absorption of heat from the steam; ıe amount of injection water will therefore depend on ıe temperature and quantity of the exhaust steam, the emperature of the delivered water, and the final tem-erature of the ejected water or that of the Hot well. n practice the temperature of Hot well varies from 00 to 130 degrees (it is more economical to keep it ıigh.) The average temperature of Injection water or the year as used in the average plant is not far from 50 to 60 degrees; under above conditions the amount of vater required for condensing will be from one to one ınd one half gallons per minute per indicated horse ɔower (depending to a VERY marked extent on the make of condenser) or say an average of about 25 times as nuch water will be required as it takes to make the team condensed. Water Departments frequently de-ire to know the amount more exactly; when they do he best way is to meter all used, but in the absence of meter Table No. 172 in connection with the following ule can be used.

RULE TO DETERMINE AMOUNT OF INJECTION WATER. *Subtract the* temperature of the Hot well from the *olute terminal* temperature of the steam plus the

latent heat units given opposite the terminal pressure in Table No. 172 (pressures are given in 1st column latent heat in 4th column) call this result A, then.

From the temperature of the Hot well, subtract the temperature of the Injection water; call this result B. then.

Multiply the amount of steam used by the engine in pounds per minute by (A divided by B) and the result will be the number of pounds of water required per minute for condensing. Reduce to gallons or other unit by Table Nos. 8, 36, etc.

The cost in power to run a good air pump and Jet Condenser need not exceed over 3 per cent. of that of the engine; it is often less; the net saving in steam through using condenser depends on the relative relation of vacuum, and pressure of steam on piston, but under ordinary conditions it will average from 15 to 25 per cent.; the steam saved is an indicator of what ought to be saved in the boiler in fuel if the remainder of plant is in proper shape.

Do not place condenser more than 20 ft. above water supply, and lower if possible.

Where several engines are in operation in or near the same room, one large or "CENTRAL" CONDENSER can be used in lieu of one for each engine resulting in increased efficiency of the combined plant.

SURFACE CONDENSERS.

Where water supply used for condensing is not fit for boiler uses a surface condenser can be used, the condensing water being passed through a series of tubes, generally of brass of less than one inch in diameter, enclosed within a cylinder into which the exhaust steam escapes; where there is not sufficient head for the water to run in and out, a circulating pump must be used while air pump is used for same purpose as with Jet Condensers.

The combined area of tubes (use Table No. 175) must be such in a good condenser that from 1.5 to 2 sq. ft. of surface is provided for each horse power of engine. On account of not being in direct contact with the steam condensed, the amount of water required will average about one-fifth more than that required by Jet Condenser, assuming same temperature and conditions. In good surface condenser, one sq. ft. of tube

face will condense from 10 or 12 to more than 14 lbs. of steam per hour, delivering water to hot well at temperature of from 100 to 130 deg. Fahr.

A better vacuum can generally be maintained by using a Surface than by a Jet Condenser.

COOLING TOWERS.

Where there is an absence of both good and bad water for condensing purposes, or where all water has to be purchased from a water department, a Cooling Tower may often be used, resulting in considerable net gain in economy. They generally depend on cooling the exhaust steam down to the temperature of the hot well by means of an air current produced by fan or otherwise passing upward through a tower filled with distributing plates, while the cooling water passes downwards. The cost to install is great, but often warranted.

STEAM PUMPS

For discharge of water by double acting plungers, see Table No. 178, or

To FIND THE CAPACITY in cubic inches of any Single Acting Pump.—Multiply the square of the Cylinder Diameter in inches, by .7854 and by the length of Stroke in inches. This product divided by 231 gives the Capacity in Gallons per Stroke. A Double Acting Pump draws water on both forward and backward motions of the Pump Rod, and has double the Capacity of a Single Acting Pump when running at Same Piston Speed.

Or multiply the area of plunger, as given in Tables No. 52 to 54B by total length of stroke per minute.

ORDINARY SPEED TO RUN PUMPS is 100 feet of piston per minute.

For feed water required, see Table No. 179.

For head in feet and equivalent pressure in lbs. see Table No. 141.

For coal required per million gallons, per day, see Table No. 180.

For steam required to operate Duplex pumps, see Table No. 181.

For horse power required to elevate water, see Table No. 163.

Or multiply the gallons per minute by 8.33. Multiply *this product by the* feet lift. The result is foot pounds

Divide by 33,000 to reduce to horse power per minute. (An allowance of at least 25 per cent. should be added for friction, etc.)

Or approximately, multiply the Gallons pumped per Minute by the Head in Feet and divide the product by 4,000 and the result will be the Theoretical Power required. Or,

TO FIND QUANTITY OF WATER elevated in one minute running at 100 feet piston speed per minute. Square the diameter of water cylinder in inches and multiply by 4. Example: Capacity of a five-inch cylinder is desired: the square of the diameter (5 inches) is 25, which, multipled by 4, gives 100, which is gallons per minute, (approximately.) Or, multiply the area of the water piston, in inches, by the distance it travels, in inches, in a given time. The product divided by 231 gives number of gallons in time named.

TO FIND THE DIAMETER OF A PUMP CYLINDER to move a given quantity of water per minute at 100 feet of piston speed; divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches.

TO FIND THE VELOCITY in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144 and divide the product by the area of the pipe in inches. Use Tables 52 to 54B.

TO FIND THE AREA OF A REQUIRED PIPE, the volume and velocity of water being given, multiply the number of cubic feet of water by 144, and divide the product by the velocity in feet per minute. The area being found, get diameter of pipe necessary by Tables 52 to 54B.

THE AREA OF THE STEAM PISTON, multiplied by the steam pressure, gives the total amount of pressure exerted. THE AREA OF THE WATER PISTON, multiplied by the pressure of water per sq. in. gives the resistance. A MARGIN must be made between the power and RESISTANCE, to MOVE the pistons at the required speed; usually 10 to 50 per cent. is allowed, depending on Pump construction, etc.

SUCTION PIPES, ETC.

In laying SUCTION PIPE A UNIFORM GRADE should *be maintained*, thus avoiding air pockets. Grade the

ɔward the supply, with a drop of not less than S IN EACH 100 FEET.

TION PIPE and its connections MUST BE TIGHT; all leak will supply the pump with air to its ty so that little or no water will be obtained. vering the suction pipe it should be tested ssure of not less than fifty pounds per square

t iron pipe may be used for suction pipe of s, but cast iron flanged pipe is best for all ıich it can be obtained. When bell and spigot ɛd it should be laid with the direction of the wards the bell.

.VES in suction and discharge pipe should be ɛS.

ON AIR CHAMBER is an advantage on long or ɔns, and is always best for single, fire, or any ch is to run at high speed, especially if of ke.

VALVE, under all conditions insures a quick f the pump by maintaining the pipe full of free from air. When a foot valve is used he area of its valve seat opening is not less rea of the pipe.

NER is always desirable but not necessary ɛr is clear and free from foreign matter that the valves and passages of the pump. The ıe strainer openings should be at least four area of the pipe, to equalize the friction of ıugh the small openings, and because some of iable to become clogged. Where strainers are must be often inspected and cleaned.

ıently happens that a pump refuses to lift !e the full pressure against which it is to work upon the force valves, for the reason that thin the pump chamber is not dislodged, but d by the motion of the plunger. It is well, to arrange for running without pressure until expelled, and water follows. This can be lacing a check valve in the delivery pipe, and a waste delivery to be closed after the pump ht water." Such a valve is also required to the *pressure* when the pump is opened for *of the valves.*

A PRIMING PIPE connected to a supply above the pump or under pressure is a convenience for quick starting and a necessity for a fire pump, and most large sizes of all classes.

HOT WATER, THICK LIQUIDS, ETC.

When hot water is to be pumped, the difficulty of lifting it by suction increases with the temperature. It should, therefore, be arranged to flow into the pump cylinder, if hot enough to vaporize when the pressure of the atmosphere is removed.

Thick liquids, like hot water, should always flow to the pump by gravity when possible, for they cannot be raised a very great height by suction, whether hot, cold or too thick.

VALVES.

Rubber, etc., valves are used in the ordinary pumps for cold water, but brass, rubber composition, or other suitable material is required for hot water or oil. For pumping salt water, or where the pump remains unused liable to rust, the piston rods and plungers should be of brass.

SUGGESTIONS.

THE STEAM, EXHAUST and DISCHARGE PIPES should all be as straight and as free from turns as possible.

In connecting the steam pipe proper allowance should be made for expansion. A gate throttle valve should be placed in the steam pipe close to the pump. Means should be provided for draining this pipe before starting.

To prevent freezing, drain the pump by opening all cocks and plugs provided for the purpose. In piping from these drips, valves should be placed close to the pump cylinders. The steam and water cylinder drips should never be connected into the same pipe unless a check valve is placed so as to close towards the water cylinder to keep it free from steam.

All pipes should be properly supported so as to relieve the pump flanges from undue strains.

Keep the STEAM CYLINDER well oiled, especially just before stopping.

Keep the STUFFING BOXES well and evenly filled with a good quality of packing. Don't screw them too tight.

Let the steam end alone if the pump begins to run badly, until fully satisfied that there is no obstruction

ı cylinder, water valves or pipes.
ump should be located, if possible, in a light, m and clean place and have good care.

PUMPING ENGINE DUTY

'" of pumping engines is the ratio of the work ed by the pump or water end to the steam or sumed.

now generally expressed in millions of foot-of work per 1,000 lbs. of steam used.

recently DUTY was expressed in foot-pounds of r 100 lbs. of coal. A pumping engine capable g 75,000,000 lbs. of water one foot high or 750,-100 ft. high was said to give a duty of SEVENTY-LIONS. This method expressed correctly the the plant as a whole, but was manifestly unfair ump contractor furnishing a good pump to be to a poor boiler, or the boiler maker furnish-oiler to run a poor pump. The deficiency in the one would have to be made up by the ex-uality of the other if a fair duty was obtained plant as a whole. The method gave no indi-f the efficiency of either boiler or pump, and ther complicated by the fact that as before out in this work, 100 lbs. of one coal might do vice the work as 100 lbs. of a certain other coal versa.

No. 179 and 180 give data relative to feed d coal based on the old fashioned method of g DUTY.

merican Society of Mechanical Engineers, rec-the unfairness of the above advised that in- "foot-lbs. per 100 lbs. of coal" the basis "foot-1,000,000 heat units" should be used, or which o millions of foot-lbs. per 1,000 lbs. of steam, given.

sis advised is the same as "100 lbs. of coal on at unit basis per lb. of coal" or when evapora-and at 212 degress is 10.355 lbs. of water per We therefore have, DUTY equals (1,000,000 f work performed) divided by Total heat ed.

ore given in different form for conven-we have below, 1st. That the work per-

formed in foot-pounds equals area of plunger (corrected for area of rod) x total total pressure against which pump is working x average length of stroke of plunger in feet x total number of strokes made during the interval under consideration. To obtain total pressure, add to that given by water pressure gauge, that due to height of gauge above water in pumping well, river or other source. Feet head reduced to pounds pressure is given in Table No. 141. 2nd. The total number of heat units consumed equals weight of feed water supplied to the boiler x total heat of the steam at the working pressure (counted from temperature of feed water) corrected for moisture or superheating.

Slip

Is best determined by fastening the plunger in several positions for a length of time equal to the duration of stroke under working conditions, collecting and weighing the amount of water that will pass the plunger under full head or pressure in each position; find the average and from it and capacity per stroke, its amount in per cent. is quickly determined.

Plunger can be fastened for 5, 10, or 20 times the duration of stroke if more convenient. In such cases, divide amount of water by 5, 10, or 20 as the case may be to get amount for the position.

When it is not known, 5 per cent. is the usual amount allowed in making estimates of discharging capacity of

e have, 1113. 7 or say 1114 heat units in one lb. of dry eam at 100 gauge reckoned from feed water at 100 ·g. Fahr. Then by rule for duty above given we have, 170 (area of plunger) x 140.39 (total pressure head) 3.5 (length of stroke) x 12,000 (number of strokes) 1,000,000 equals 1,002,384,600.

Dividing this by total heat units consumed or by 14 x 10,000 (lbs of feed water used) or by 11,140,000 e have for duty under the assumed conditions EIGHTY INE MILLIONS.

From the above should be deducted a proper amount ›r leakage or slip as previously determined or assumed.

All of the data in the above example was taken at ındom, but represents fairly well an average pump of ıoderate duty.

DUTY OF ABOVE PUMPING ENGINE, determined in old ·ay.

Assume all conditions the same as above given and ıat the coal used during the test weighed 1250 lbs.)ividing 10,000 lbs. (amount of feed water) by 1250 ve have 8 lbs. as the amount of water evaporated from ı temperature of feed of 100 degrees at pressure of ıoo lbs. Equivalent evaporation from and at 212 deg. by Table No. 174 equals 8 x 1.16 or 9.28 lbs. It is not necessary to know equivalent just given, but it is of assistance in comparing coals, performance of boiler, etc.

The work done by the pump end, by rule before given equals 170 (area of plunger) x 140.39 (total pressure) x 3.5 (length of stroke) x 12,000 (the number of strokes) or 1,002 million foot pounds. As 1250 lbs. (or 125 x 100 lbs. of coal were used) dividing by 125 we have 81.6 millions as the duty of the engine per 100 lbs. of coal used under the conditions given.

It needs no discussion to show that depending on the coal used, by this last rule the duty might vary from 70 to 90 or more millions; hence the manifest unfairness of applying it to PUMPING ENGINE DUTY.

HORSE POWER OF PUMP.

Dividing work done in ft. lbs., 1,002,000,000 ft. lbs. by 600 (minutes in ten hours or duration of test) x 33,000 we have approximately 50 horse power.

COAL CONSUMPTION PER HORSE POWER HOUR.

From the data we have 1250 lbs. divided by 10 equals *125 lbs. per hour.* Dividing this by 50 we have 2.5 lbs. *f coal per horse* power hour, as the amount under the *umed conditions.*

... cubic feet per second.

... U. S. gallon per seco

... California miner's inc

... U. S. gallons per

... U. S. gallons per day

... acre-feet per year.

... acre-feet per day.

... divide any of

... of ONE M

... any other

... tables

... rainfal

... conden

... evaporation

... U

From GROWING CROPS, grass, etc., it is frequent- twice as great as from adjacent barren land (see bove). This is on account of the greater exposed surace per unit of area including surface of crops.

From ROUGH, STONY OR STEEP RIVER BOTTOMS, here the difference between maximum and minimum un-off of the stream is great (being 50 to 1 and even more in many cases), the evaporation during the hot ummer days is usually excessive. During an extensive ater-power investigation, the author found the evaportion from such a river bottom, Cold River, near Rutand, Vt., to be such that the flow of the stream in the mountains was nearly twice as great as at a point some our miles below, during July, 1898. The geological ormation was such, that no water escaped under the urface, while several small brooks from springs enered the stream between the points mentioned.

FORESTS.

Such examples as the above show without argument why thousands of small and many large mill rights have been abandoned all over the country and at present have no intrinsic value, except (in the opinion of owners), when it is proposed to take stream for water supply. The forests protecting the streams have been removed, without, in many instances, any thought of other than immediate profit through the sale of timber; had it been cut in a scientific manner, the streams would yet be giving their former efficient minimum run-off and there would yet be timber to cut. Forests reduce the necessary capacity of storage reservoirs for power and water works purposes by retarding, holding back, the stream flow or run-off, reduce materially the evaporation from that that does run off, and in other self-evident ways tend to reduce the ratio between maximum and minimum run-off or between freshet discharge and dry season flow.

Forests increase as a rule the amount of water available from a given area of ground or well supplies. The exception to this rule is in certain clay soils, where it has been observed that the soil for a considerable depth was dryer before than after the removal of the forest. The trees drawing from the soil, dried it. After they were removed the soil contained much more moisture. he author cannot believe, however, that in such cas

l by certain water companies, especially on Slope.

rs, instead of using their own judgment, and noney for attempts at getting water, would natter to a specialist, there would be less fail-)lated or other supplies; the money expended would in many cases pay for the specialist ater besides. No business is so little under- the people at large as "water supply." The vho can say that every nine out of ten people ıring an investigation did not tell him "just ɔ to insure success," with seldom two opinions ıard to find.

Crops.

in localties of excessive rainfall, crops, as .icated, absorb all light rains, allowing none to soil or stream.

lowing table of amount absorbed by the or-ops found on the drainage areas of many water will be found convenient when making proper s from total water, for actual amount availa- vater supply."

Table No. 192

BSORBED BY GROWING CROPS IN INCHES DEEP PER MONTH DURING GROWTH.

grass (hay)	4 inches to 6 inches
	3 inches to 5 inches
	2.8 inches to 3.5 inches
	2.8 inches to 3.0 inches
	1.0 inches to 2.0 inches

Artesian Wells.

m "artesian" as now used covers both flowing lowing wells.

if not the majority of artesian waters used for pplies contain nitrogen as nitrates in larger han ordinary surface water.

rowths use food containing nitrogen, but thrive away from sunlight. It is therefore ore such waters in covered reservoirs. It may :xpensive to not construct such reservoir in laces and instead, pump constantly from the which case the water need not be exposed to

"The village is to be congratulated; our people can soon abandon the filthy pond supply. The well yesterday, at a depth of only forty feet reached a flow of 15 gallons per minute that is pure and white as crystal; it comes from the *bowels* of the earth beyond the reach of contamination. Drilling will continue until a supply sufficient for many years to come is obtained; it will then be piped to the distribution reservoir, into which it will flow without the use of pumps. Before deciding on the plan the committee visited many places that had grappled with this same problem, and as a result the citizens will soon enjoy the benefit of placing its affairs of importance in the hands of such zealous and intelligent gentlemen.

At the meeting on Monday evening, the committee will explain their plans; the methods adopted at various places and other matters of interest and value, but as the majority of the citizens have already visited the wells and seen for themselves what can be done, there will be few if any votes against the additional appropriation needed, though a full attendance is desired."

The above is extracted from a recent editorial. The appropriation was voted; drilling was continued; in fact everything increased or continued but the supply and it, at 400 feet deep, was no greater than at 40 feet.

On being called to investigate, the author found that with the distribution reservoir (150 feet distant) empty, the well ceased to flow more than two or three gallons per minute. Analysis of the well water was made; reservoir again filled and analysis of well water, which was again flowing about 15 gallons per minute, was again made after the introduction of Lithium chloride into the water in the reservoir. Its presence in the water of the well was sufficient to convince all, but such as are in every town, that cannot be convinced or removed from the narrow rut of opinion, that the "bowels" of the earth had far less to do with the supply than "bowels" located (when at home) on the water shed of their pond supply. Having made one mistake, they fear to vote money for their only relief, FILTRATION.

An individual owner, after spending several hundred *dollars ($4,000)* on the supposition that "a BIG body of *water like the* Hudson river was BIG enough

force a little six-inch stream up the short vertical distance of 400 feet through his wells situated on top of the adjacent Palisades," after drilling 100 feet deeper, to prove he was right, accepted the author's advice and stopped work.

Many in authority are next door to insane on the subject of "what a well can do," and when it don't happen to do it, they are willing and anxious to buy the first of the "pull yourself up by your bootstraps" arrangements that is offered or put in one or two of their own.

The supply feeding any well or system of wells depends on natural law and conditions ONLY.

The average rate of discharge from a well or wells cannot exceed the average rate at which rainfall or other water percolates into the drainage cone per unit of area, nor can it be drawn from this cone by any means or method at the well faster than air or water, gallon for gallon, will penetrate the rock, or soil at or near the surface or such portions of the surface of the cone as may embrace the source of well supply. That this rate of penetration is slow is well known to those who have observed the slow rate at which water will pass through stone household filters; one half gallon per square foot per day under one half foot head is a fair if not high average rate for the discharge of such (so called) filters. In order to testify in condemnation and other proceedings, the author has made several hundred tests of soils and rocks from different depths in order to show their capacity to receive hold and discharge water. The average results for certain rocks are given in condensed form in table No. 193, while those for sands, gravels, soils, etc., will be found in table No. 194.

Table No. 193

RATE OF FLOW INTO AND OUT OF ROCKS PER DAY, IN U. S. GALLONS.

Name	per square foot	per acre
Sandstones	0.1 to 0.3	4000 to 13000
Limestones	0.004 to 0.063	160 to 2500
Granites	0.01 to 0.1	400 to [illegible]
Conglomerites	0.01 to 0.4	400 to [illegible]

Rate of Flow Into and Out of Rocks per Day, in U. S. Gallons.

Name	per square mile.
Sandstones	2700000 to 8360000
Limestones	108000 to 1701000
Granites	270000 to 2700000
Conglomerites	270000 to 10800000

The small rate of flow shows the importance of proper distribution of wells across strata in order to get maximum supply for given expenditure for drilling, etc., in practice, it will not give results greatly in error, to assume the rock strata adjacent to wells to hold in gallons the above quantities per unit area one foot deep.

Red Sandstone and Traprock Formations.

In red sandstone (trap rock on top) formations the drainage cone, instead of taking most of its supply from its edge, where the strata intersected by the bottom of the wells, as in the Florida, Atlantic Coast and other cases before mentioned, pierces the surface; much is obtained from intermediate areas draining through "faults" and other nearly vertical passages from the surface to the strata pierced by the well. The water from within the rock itself drains to the passages of least resistance, and while the general line of drainage is in the direction of "dip" of the strata, other lines of the drainage radiate to the general line.

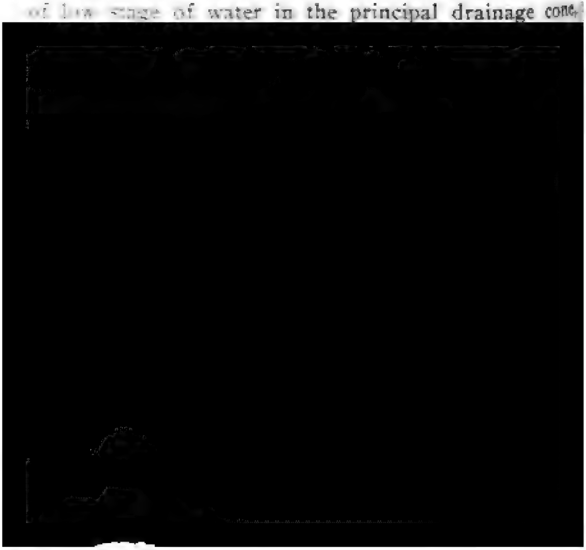
The center line of this principal drainage cone, or more accurately triangular prism of drainage, is in the direction of the "dip" of the strata, N. E., S. W., or, as the case may be, from the well to the point where the strata pierced by the bottom of the well intersects the surface; the height of prism equals depth of well, see Fig. 15, page 75, where B. G. of the triangular prism B. G. D. F. equals depth of well. The length FD. of the intersecting line of strata with the surface effected by the well will depend on compactness, depth between layers, etc., of the sandstone; with average sandstone, such as that under the surface of Essex and Passaic Counties, New Jersey, the angle subtended at the well by the two limiting lines from the ends of the above mentioned *intersecting* line will be about 45 degrees.

The maximum gradient along centre line of prin-*cipal drainage* cone is in direction of and equal to th

"dip" of the strata; the rate of grade of limiting line, of drainage in any other direction within the above mentioned intersecting lines, can be easily computed, knowing the dip. It is simply a diagonal on an inclined plane. The tendency of the body of water as a whole contained in rock such as sand or limestone, is to drain in the direction of the layers of stratification or "dip" to the well; from an opposite or diagonally opposite direction, any water passing to the well must pass diagonally across the layers, and the area effected in such directions is small except in very low stage of water in principal drainage cone. With a dip of rock of 1 inch in 12 inches, the greatest distance that the author has known a well to drain in exact opposite direction to "dip" was about six times depth of well.

On account of the small amount of water certain other rocks will absorb, and the much smaller amount some of them will "deliver up" for well supply, the drainage from such opposite direction is nearly zero. In the same district or locality, the ability of stone to absorb and deliver often varies with the depth, because of increasing compactness of the stone.

Each foot increase in depth of well increases length of principal drainage cone. With 1 inch per foot dip the increase in length is 12 feet; with 0.1 foot per foot dip, 120 feet, etc. As before indicated, except in case of low stage of water in the principal drainage cone,



noderate supply; to increase it, the depth was increas- :d and salt water was obtained. At Carpenter Brothers' juarry, on the Hudson at Ft. Lee, a well 150 feet deep lelivers brackish water. One mile inland the Convent well at a depth of nearly 1,000 feet (at time of author's visit) the delivery was but a few gallons per minute: the length of principal line of drainage cone being less than one mile; the surface soil, chiefly clay was steep, allowing water or rain to drain rapidly over and across it without percolation into the drainage cone. At Bellville, N. J., the City of Newark have since constructed wells delivering, so Chief Engineer Sherred informed the author in Feb., 1901, seven million gallons per day. They are in the same strata and but a few miles below those considered in the investigation.

GRANITE ROCK.

Few wells in granite rock are delivering water sufficient for public supply while not one in ten drilled, is delivering sufficient for individual use. The author has in mind twenty wells costing an aggregate of $15,000, that are not delivering a total of more than 60 gallons per minute. Such wells are not of enough popular importance to be here considered.

COST TO DRILL WELLS.

The cost to drill varies with the diameter, location, etc., but averages about $3.00 per foot; to this should be added pipe, appurtenances, transportation of drilling outfit, etc. Deep wells, especially when constructed with poor outfits often cost more on account of "stuck drill," "off centre," "fishing," etc.

In the oil regions where good outfits are plenty, the cost for a six inch well is often as low as $1.00 per foot, drilled.

DRIVEN AND OPEN WELLS.

Source of supply is generally local. The storage capacity feeding the wells is equal to the capacity of the drainage cone to hold and deliver water. Average sands and gravels will deliver from 80 to 90 per cent. of the contained water. The capacity of soils vary. The White Plains, N. Y., 22 acre basin adjacent to the open wells is a fair one in which an engineer would locate a well supply. To prepare for giving testimony on behalf of *the Farmers' Loan* and Trust Co., as Trustee for the *bondholders, and* the water company stock holders a

well, the author as chief expert witness in condemnation proceedings, had to make over 300 mechanical analyses of the sand, gravel, quick-sand, soil, peat, etc., in the drainage cone. The average capacity to hold water was in excess of 36 per cent. Vis, that for every 100 cu. ft. of material in the drainage cone, there was a storage of 36 cu. ft. or 269 gallons of water. A peat bed with its contained silt, was found to hold 70 per cent. of its own volume in water. More in detail the average results were, as given in the following table.

Samples were taken from all depths to 55 ft. and uniformly distributed throughout the basin.

Table No. 194

CAPACITY OF SANDS, GRAVELS, SOILS, ETC., TO HOLD WATER.

Quick-sand, 45 to 52 cu. ft. of water per 100 cu. ft. of quick-sand.

Coarse sand or fine gravel, 22 to 28 cu. ft. of water per 100 cu. ft.

Medium sand, 32 to 38 cu. ft. of water per 100 cu. ft.

Peat, with silt, 70 cu. ft. of water per 100 cu. ft.

Ordinary top soil varied from 26 to 50 cu. ft. per 100 cu. ft. depending on the amount of clay and organic matter.

AMOUNT OF VOID IN SANDS, ETC.

Table No. 37 can be used, but not accurately for above ırpose.

Rate of Flow into Wells.

The gradient line of drainage to the bottom t the wells with water just outside of them 8 inches .gher than inside, was found to be at the rate of 15 :et per mile. Below this line when pumping at the ıte of 600 gallons per sq. ft. of opening into wells per ay no water could be drained. If rate of infiltration as decreased by construction of additional wells, this ıte of gradient would be much less for the coarse sand rata adjacent to the bottom of the wells; as has been oticed by the author in other cases.

A rate of flow of one mile per year through a sand ed, such as that of Long Island, toward the ocean or ater course, and gradient of 8 to 10 feet per mile are onsidered fair averages by certain investigators. This .te of flow and gradient are certainly exceeded and :duced respectively in the case of many isolated well ants.

It must be remembered that the average permanent ow from wells cannot exceed that of the average rate 'hich rain falling on the drainage cone, plus such water s may in exceptional cases be brought to the drainage one by brooks or other means, reaches the interior of he drainage cone, and that the total amount per an- ıum when forests, crops, evaporation and other matters re properly allowed for, will seldom exceed one-third t (area of drainage cone plus outside areas furnishing art if any of supply) x depth of rain fall in feet. To get all of this, wells must be properly distributed in the ırainage cone.

Salt Water in Wells.

No fresh water from wells near the ocean, is derived rom sea water, though such wells may be piped through he salt water itself to the beach or bottom below, as at he pier at Nantucket. The difference in specific grav- ty of about 3 per. cent. between the two waters, is suf- icient to force the water backward or upward but a mall amount, in inches perhaps, but not 400 feet as sup- osed in the Hudson river well case before mentioned.

The water coming from a higher level, back in the ands from *the ocean* drains toward it, and can be *umped from the well.* In exceptional cases, such as

cation was simply a matter of straining through sand. ne case would be different, but it is not.

Again forced pumping for a great length of time ends to force channels through the sand, and there is ften direct passages from a contaminated source to the vells, allowing even little chance for straining.

In good locations, driven wells will often furnish the est possible supply for minimum cost. The author nappens to be a director in a water company that adopted driven wells for "summer supply" as being cheaper than to provide the additional storage necessary to meet demands during the annual "dry season."

SPRINGS.

Are fed from the water contained in the "drainage cone" above them. In flat country, as in the case of Well Supply, one-third of the rainfall may be delivered to and discharged by them. When forests cover the greater portion of the drainage cone, the amount may be exceeded except in cases of steep mountain sides, with strata unfavorable for entrance of water. In such cases it is often much less. Proper consideration of the flow of water to and from springs involves exactly the same procedure, relative to the storage capacity of rocks, soils, etc., as given under Driven, Open and Artesian Wells and will not be here repeated.

In the average small municipality of about 1,000 people especially if situated in a farming district, the people as a whole "pin their faith" to any spring or springs that they know "does not run dry." Often this confidence is not misplaced, for the underground reservoir (the porous soil containing the water that feeds the spring) is often large in proportion to the flow of the spring or springs. If investigation shows that such springs are free from contamination and are adjacent to or within reasonable distance of the line where a main pipe ought in the future to be laid from a more adequate source of supply, it will be well to consider adopting the springs as a temporary source, constructing a small storage basin at them and connecting it by pipe line to the main line of the future, which can be laid from municipality o opposite the springs. In this way often the total irst cost will not exceed one-third what it would be if *he entire plan in* the mind of the engineer was first *rried out.* People in such small municipalities ofte

need the object lesson of water actually flowing from their kitchen faucet or from a hydrant, before they are willing to vote a sum sufficient for a works complete from an engineering standpoint. It is often their first bond issue and the father of the works and his associates must be prepared to meet the thousand and one honest objections brought against the project. If he cannot, using tact, he had better let the project drop, and await a big fire in their midst. Often however by proper procedure the people will vote a small sum, if the Springs are to be the source, while they would vote down any project involving the storage of the waters of a stream. Again money will nearly double itself in a dozen years and it does not pay to provide for the wants of the people too far ahead. Provide enough to show the benefit of a system, quietly secure control of future supply and soon income will be sufficient to pay bond interest and running expenses; insurance rates will have been reduced, conflagration checked, wells have been voluntarily closed, and the people will demand extensions to distribution system and the annexation of more supply, frequently regardless of cost. The amount saved in insurance will often be more than their water rent, the Fire Department is the most popular organization in town, the Water works has no enemy.

Water from springs will as a rule give better satisfaction than water from adjacent streams even after filtration. A good water in the first place is always better than one made good by artificial means.

In the summer of 1899 the author designed and supervised the construction of the water works for High Bridge, N. J., population about 1,000. The general plan contemplated a supply from a distance ample in quantity and by gravity. Within a few hundred feet of the direct line of the future main are several little springs; at two of the largest, storage basins were constructed and connected with the main pipe, which was stopped at the upper one. The aggregate almost constant flow (summer) of the springs was 40 gallons per minute. This flow plus the small storage of possibly 30 days is all the Borough has to depend on; that they are satisfied with it is shown by the following as quoted from letter written by Mayor Walter Brinton and dated April [illegible] 1901. "I am glad you remember the trials, uncertain

nd inconveniences attending the operation of building ur water plant. It is our intention, as you suggest in— o carry the plant to every part of the Borough, but we .re not justified at this time to make unprofitable exension preferable to improvement which will net us a good income and which we are now engaged in doing.

"I am gratified to state to you that our water plant nas been giving most satisfactory results. During all the drought of the latter part of the season of 1900 and the early part of the present year we had sufficient water to supply all Borough subscribers in addition to supplying twelve to fifteen locomotives with water for the C. R. R. Co. each day.

"Our plant is on a paying basis at this writing and giving entire satisfaction in every way. I doubt not that within the next year the Borough will order the construction of the large reservoir as planned by you on the D. L. Apgar property."

TYPHOID FEVER

Mortality, average 10 per cent.

Most investigators believe that the bacillus discovered by Erbeth in 1880 to be the germ of Typhoid Fever.

Its length is from two to three times its diameter, which varies from one-half to one micron; its ends are rounded.

Because of the fact that it is found in other than living bodies, it presumably thrives on decaying organic matter.

It can resist being frozen in ice or earth for months but will die quickly in a temperature of 135 degrees Fahr.

It will live for months in excreta from typhoid fever patients and for this reason, such excreta should be *cremated* without delay, not buried in the usual way for the germs may pass through such water courses or channels in the soil as were mentioned under "Driven Wells," direct into a stream, wells or reservoir used for water supply. Such cremation does away with danger of careless burial and prevents possibility of epidemic by water carriage of germs.

In the New Haven case, April, 1901, more than 500 *cases were directly* traced to a single case of typhoid *State engineer* T. H. McKenzie, C.E., member of St

[illegible]
[illegible]
[illegible]
[illegible]
[illegible] issued [illegible]
[illegible]
[illegible] listened. [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] the [illegible]
[illegible]
[illegible] demands
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

t New Haven after the outbreak, from various por-
ons of the reservoir failed to show the presence of any erms. This fact is not proof that they were not there wo weeks, or even one day previous to the examina-on; in fact, their absence would tend to connect the pidemic more closely with the individual case of typhoid or reasons before given. Multiplication of the germs nder conditions favorable for their rapid death is not robable, and if germs had been found after the epi-emic had commenced, they more likely would have een more recent arrivals from the same source than aveling companions of those that caused the epidemic.

It may assist, it will do no harm, to examine the water f the reservoir, but it is best to look farther; up the tream, along its banks, in the cemetery, at the oyster oat, or other place below and above the sewer outlet, here the tide ebbs and flows accommodatingly past it, urnishing food for much of the sea food consumed, while it is there being kept alive and fattened, awaiting urchase. Look also at the ice cream, frozen though may be; at the dairy two hundred miles away that urnished the milk from which it was made. If the atient had recently returned from Jersey City, Pekin, Manila, or Chicago, look there.

EPIDEMIC OF TYPHOID.

The first cases appear in about ten days after the germs have been distributed by the milkman or water lepartment; milk can washing with infected water be-ng about as direct a way of carrying germs to a city is drinking directly from the stream. In a few days, possibly a week afterwards, if every precaution has been taken by attending physicians and the surround-ings from a sanitary standpoint are good, the cases will reach a maximum. About the third week, the epidemic will begin to die out and unless hastened by other com-plications the deaths would mostly occur the following month.

FLIES AND MOSQUITOES.

Flies, mosquitoes, etc., are conveyors of germs and after visits to piles of decaying organic matter, excreta, etc., containing germs and a hearty meal, they are often conveyed by gale or wind many rods or miles to an in-viting water pitcher, cake or dinner table, there to de-posit saliva or excreta.

[illegible]

esults of a water analysis are generally express-rains per gallon or other number of gallons, r million, etc. While Tables Nos. 2, 8, 36 and ill assist, the conversion table below given will l a more convenient assistant in correctly inter-g or comparing results.

Table No. 195

WATER ANALYSIS, CONVERSION TABLE.

r million x 0.13328 equal ounces per 1,000 U. S. s.

r million x 0.00833 equal Commercial lbs. per U. S. gallons.

r million x 8.33 equal Commercial lbs. per 1,) U. S. gallons.

r million x 0.058 equal Grains per U. S. gallon

r million x 0.07 equal Grains per Imperial gal-

r 100,000 x 0.583 equal Grains per U. S. gallon

r 100,000 x 0.7 equal Grains per Imperial gallon.

HARD WATERS

scussed under the head of "Boiler Waters." oduce derangements of the human system.

SOFT WATERS

e derangements of the human system more fre-among those constantly using than do hard To change from one to the other suddenly will, st people give cause for, often, serious complaint for a time.

TURBID WATERS.

not had traced to them serious epidemic when ising the turbidity has been free from germs. ef reason for fear in using them is because the ivided clay or other matter in suspension or has been derived from soils, etc., favorable for tence of typhoid germs and associates, and that mbrace and deliver germs to the water consum-: Mississippi river contains, at times, as high as irts per million gallons of solids, chiefly silt. ounts, by table No. 195 to about 9.5 tons per mil-lons. The average amount in the river is about s, or about 1.5 tons per million gallons.

ut sedimentation, filtration, etc., each citizen *of the raw* river water swallows his share of

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

the surface. In ordinary reservoirs exposed
ıd little circulation takes place below 20 feet
. This accounts for the more frequent "purg-
/orking" of shallow reservoirs while the same
he same time in deep reservoirs on the same
: often free from vegetable and animal tastes
. An exception to this rule was the Quincy,
'oir, where algæ growths caused trouble
:r was more than 10 ft. deep, but not when 10
The decaying organic matter furnishing the
ostly on the bottom and if not disturbed by
, the organisms thriving upon it will not be
be distributed throughout the water and as-
propagate, live and die by countless thous-
he favorable action of warm sun light that
the entire depth of shallow reservoirs.
an reservoir, especially if not exposed to the
ıod or pure water can be kept indefinately
:terioration, while in such a reservoir, nine out
ers will improve with age. Any stored water
de safe by proper filtration and aeration.

RESERVOIR BOTTOMS.

'e indicated algæ and other growths are re-
clean reservoir bottoms; therefore, to remove
ı soil containing organic matter, is a proper
·e. Farming lands used for crops, etc., should
be removed to a depth of from 10 inches to a
ıd under forests, about one-third less; muck
swampy material to a few inches under solid
t is desirable that the soil be stripped to that
re the organic matter contained will be less
r cent., but if stripped as above suggested, fre-
ıe amount contained will be less than 5 per
ɛ amount of organic matter is easily deter-
or near the work by taking samples of the
ess of a pound or other unit weight and thor-
ying at a temperature of boiling water. A
ıousehold double boiler or oat meal cooker
:r every purpose of a laboratory outfit. Take
ɔund or other unit weight of the dried mate-
ıeat it to a bright red and then weigh. The
ɛight divided by unit weight of sample used
cent. of organic matter. Table No. 7 and oth-
ın tables in this work will facilitate calcu-

lation. Use good scales, but if they are not sensitive enough to estimate quarter ounces take four or more times the weight.

Swamp and Other Colored Waters.

Color from peaty matter, cypress, cedar, bogs, etc., can not always be removed from water for reasonable cost. Certain of the colored waters possess curative properties; many are in use giving satisfaction as public supplies. On the other hand, epidemics of diarrhœa have often been traced to the use of such waters. Malaria, etc., can be contracted either by aid of air or water as a conveyor, and many cases are annually attributed to the use of swamp water. Ordinary filtration will remove much color from such waters, because much of the color imparted is on account of organisms and other matter in suspension in the water being colored and when they are removed by filtration, the per cent. of color is reduced. The remaining soluble coloring matter can often be reduced to an amount, not apparent to the average eye by alum introduction. The aluminum hydrate precipitate or at least a portion of it formed on introducing the alum in waters containing carbonates, on account of their decomposing effect on the alum (sulphate of alumina) combines with the soluble coloring matter. When the use of alum is for this specific purpose, its cost will generally be prohibitive, but if it is used in connection with mechanical filtration plant, there is little additional cost. If the water is deficient in carbonates, they must be added or efficiency of color reduction will be correspondingly reduced. Proper purification plant, with or without the removal of the soluble coloring matter, depending on its nature and effect will remove all cause for complaint and danger.

Artesian Waters.

(See Artesian Wells, also "Filtration.")

Ordinary Well Waters.

The "come from the farm" label attached to produce, butter, cheese, milk, with most people is a stamp of purity. Those who believe it, better live on the average farm a while or at least be engaged in laying pipe lines or constructing reservoirs in such neighborhoods. The average farmer, for convenience and so he "won't get wet when it rains" has his well and water close either under or very close to the back stoop.

he chickens are also handy on one side a short dis-
:e back, while opposite are the pigs, and next to
n in the rear are the cow stables, that break the
d of a stormy or heat the air of a wintry day. In
rear are the horses and general manure heap, all
hin as close a distance of the nearly central well as
general convenience and size of the buildings or
:ds will admit, while scratching away between will
found all the chickens and ducks (except those run-
'g around the house or as may be on the front stoop)
at he owns. No wonder a farmer so situated re-
ntly remarked "Don't put any two foot pipe line near
at well, it might dry it up and I cannot afford to
rt with it; why, last summer every spring and water
urse on my 160 acres went dry, but she never flinch-
l but gave us all we wanted and helped out the neigh-
ors besides." No wonder it did not dry up; by using
condensor, water tower, etc., we can return nearly
l the water used in steam making to the boiler; by a
mewhat similar economical process the farmer had
turned nearly all and more besides to the well. Such
ells, and in fact, 99 out of every 100, ought to be con-
emned. While they are permitted to exist we must
ll Typhoid "the germ of the country districts" for
atistics prove that the death rate in rural communi-
es from it exceeds that of cities.

Perhaps if there was a way to avoid taking water
om the country districts the death rate of many mun-
'palities would be much decreased. Filtration, etc., is
le only safe guard a city can have against contamina-
'n of its water supply, having its source in the aver-
:e Farmer's Well.

VEGETABLE AND ANIMAL GROWTHS.

The microscopic and somewhat larger sizes of vege-
ble and animal organisms that make their periodical
pearance in certain reservoir and well supplies in
rge numbers, giving forth a terrible taste and odor in
e and worse in death, are not of themselves difficult
removal by filtration or filtration and aeration. One
ust know exactly what organisms of those present are
using the trouble. A method that will remove the
st cause of complaint may set up conditions most
vorable for the growth or propagation of other or-
'isms contained; giving trouble from the second

[illegible] worse than the first. The presence of such organisms in a supply produces diarrhoea, dysentery, and other complaints often in epidemic form, run down the human system and make it more susceptible to the reception of other more fatal diseases. Again the presence of such growths prevents its use for many industrial and commercial purposes. At Bethel, Conn., in [illegible] the hat factories had to shut down on account of such growth in the water supply. A filter plant was constructed by W. B. Ritter & Son, and the trouble has not since been repeated. (See letter, under "Filtration and Aeration.") Oyster industries have been obliged to move from places furnishing such supply or get a less price for their output. The fresh water used in "fattening them," coloring and imparting a "fishy taste and smell" to them.

Sewage in Water

Gases from an unhealthy source, giving a carbonic acid gas or soda water look, rough straining through earth, as in the case of the farmers well, often give such a sparkling appearance as a 50 per cent. solution of sewage, that the average individual will use it for water. Such a mixture, unless heated, has little taste or odor, other than that of water from a healthy source. It frequently has however a decided blue tinge and as one expressed it "a greasy look." Such a water coming from a well within six or eight feet of a cesspool is

nth. At Altona, population 140,000, all drank of the ne cholera charged Elbe after it had received the wage of 800,000 people, but AFTER it had been operly filtered. NO PERSON died from drinking the urified city supply at Altona.

BOILER WATERS.

It is a common mistake to assume that a so-called are mountain spring or soft water is best for boiler ses. Pure water frequently exerts powerful corrosive ction, especially at the point of entrance to the boiler, here gases are driven out of solution by the action of eat and at once attack the boiler. The dissolved oxy-n in all and the carbonic acid in many waters corrode e iron. Mine and river water receiving the discharge manufactories often contain free (generally sul-uric) acid; organic acids are also present in some aters; all are very injurious.

Magnesium chloride, present in many waters, at tem-rature of about 310 degrees Fahr. re-acts with water form magnesium oxide and hydrochloric acid, the id attacking the boiler in greater or less degree, de-nding somewhat on the amount of calcuim carbon-e present. The addition of common salt to waters ntaining magnesium chloride checks corrosion to a rtain extent on account of the two chlorides, sodium d magnesium combining and forming a stable double lt.

Nitrates in water are also injurious.

Loose sludge or mud is usually formed of calcium rbonate, magnesium oxide, or carbonate; the magnes-n oxide being formed as above mentioned.

Such sludge by frequent blowing off need not ser-isly interfere with economical running of the boiler. If water contains calcium sulphate, which is quite in-luble in water above 212 degrees Fahr., hard incrusta-n will be formed in the boiler, and it in forming en-ops much of the above mentioned sludge, such alum-im, iron, silica, etc., and much of the other material, neral and vegetable that may be in the water. The oper use of a boiler is to EVAPORATE WATER, d the author is not a believer in making of it an ap-atus for the development of chemical phenomena. If d water *must be used the* best way to remove scale *y mechanical scrapers*, etc., but the better way is to

[illegible]

Table No. 196.—Continued

:ase (from condensed rater).	Corrosion	Slacked lime and filtering. Carbonate of soda. Substitute mineral oil.
'ganic matter.	"	Precipitate with alum or ferric chloride and filter.
hloride and sulphate of magnesium.	Incrustation.	Addition of carbonate of soda, etc.

1-16 inch thickness of scale in ordinary boiler increases fuel bill from 5 to 10 per cent.

1-16-inch thickness of scale in ordinary boiler in- :reases fuel bill from 5 to 10 per cent.

FILTRATION, AERATION, ETC.

Many centuries ago the Chinese, Egyptians, and oth- :rs placed aluminous rocks in their water jars to assist n removing impurities. In 1839 James Simpson con- tructed a filter-bed plant for the Southwark and Vaux- iall Water Co., that in no essential detail was different han the present style of bed. If rates of flow, etc., iad then been properly understood, the purification ef- ected would have been as great as by modern beds. From time to time since then, chiefly in Europe, filter- eds have been constructed on the same general lines intil about 20,000,000 people are now furnished daily vith water purified by filter-beds. For many years alum vas used in connection with filter-bed operation, but its ise is fast becoming obsolete except with very turbid or much stained waters. Mechanical filters are the out- ome of American genius but differ not in principle from he filter-bed and alum method. The chief difference s in the rate of flow; it being from 50 to 100 times greater in the mechanical, and in the methods of clean- ng the bed.

The beneficial effect of aeration was noticed centuries go, while as early as 1846 the use of alum and air or water clarification was in use in Conn. See page 361.

The use of air underneath a filtering medium for the urpose of assisting in the work of purification and for gitating the bed when cleaning was first used in 1889 y the author. The first public supply to be purified and ilter to be cleaned by this method was at Nantucket nd constructed by him in 1892. The following is uoted from the Massachusetts State Board of Health Report: "*The results* are particularly interesting as

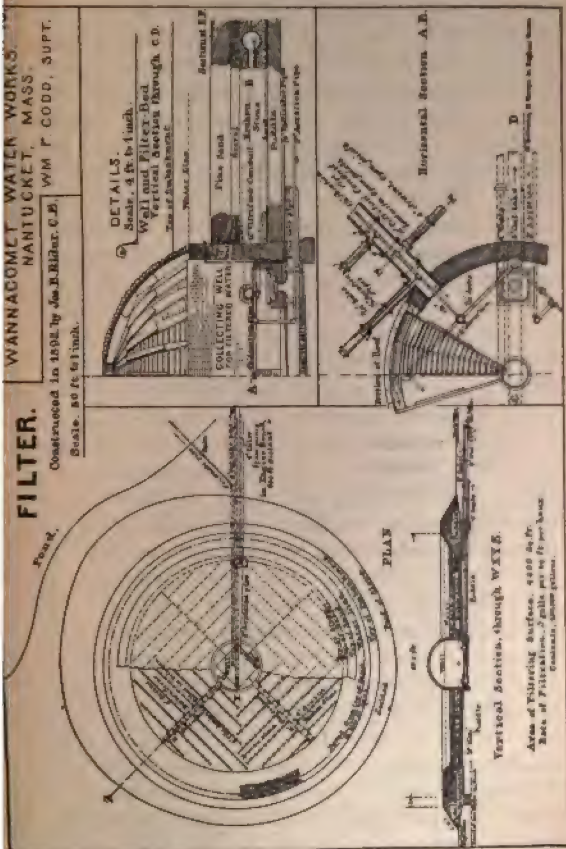
[illegible] disagreeable [illegible]

[illegible] was absent in both [illegible]

Name of organism	Number per 100 cubic centimeters
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	700
Anabaena [illegible]	[illegible]

Sixty-eight per cent. of the organic matter as rep-
resented by the albuminoid ammonia was removed;
3 out of 16 genera present were filtered out; creno-
thrix, that organism giving much trouble in Well Sup-
plies, and anabaena spores were absent in the filtered
water, while out of a total of 216,000 anabaena per 100
cubic centimeters, but 3,600 remained; 99 1-3 per cent.

FIG. 34.



NOTE.—The scale marked is not correct, the drawing having been reduced so that scale is now approximately 65 *ft. to the inch.*

were therefore removed. The iron was reduced eleven-twelfths; this was because of aeration and the fact that crenothrix, an iron secreting organism was removed.

An average of 96 per cent. removal of micro-organisms was effected during three months period of bad water. The Nantucket Filter, though it can do such efficient work, as shown by the analysis, is not perfect; but as it is the Pioneer of its kind, Fig. 34 is introduced to show its construction, and point out the methods there adopted that should be avoided. In fairness to the designer, it should be stated that the original plan called for a filter bed and collecting well below the level of the pond, but that expense of quicksand excavation, etc., made necessary its abandonment in favor of plan adopted. The air used was from the hot engine room; it should have been taken from a cooler place. To save expense, while one side of a duplex pump is pumping water to the top of the filter-bed, the other side is pumping air to either the drains or collecting well or both. Under small heads, by changing clearance space of pump, this can be done, saving cost for compressor, but it is not good practice. The collecting well as constructed concentrates the heat of the summer sun, even as a tin roof, the temperature in well being frequently in excess of 100 degrees Fahr.

Clay for embankment being very scarce, the depth of water over filter bed is too shallow, being about 20 inches. After filtration, the water is pumped to an exposed open standpipe, there again to remain in the sunlight until used, in fact every successive step tends to heat up the water, with final exposure to the sun, when the reverse should be practiced. The result is that there are certain days when it will not do its work properly, but any plant constructed on the same general lines, avoiding what is above pointed out, and what would have been avoided in the first design, will remove all cause for trouble from such organisms as were there present. The success of the author in constantly removing them for periods of ten years where all precautions have been taken, proves this. The cost of the plant at Nantucket, including engineering, was about $4,500. Cost to operate, about $2.08 per million gallons.

In 1890, as before mentioned, the Hat factories

Bethel, Conn., had to shut down on account of the quality of the water supply; its taste and odor from vegetable and animal matter was (if possible to be) worse than at Nantucket.

A filter, with provision for aeration, and submerged collecting well, was constructed by the author and his father and was put in operation three years prior to the much quoted Lawrence Filter. Continued analyses showed removal of over 90 per cent. of the organic matter as represented by the albuminoid ammonia, and 99 per cent. removal of micro-organisms with all taste and odor; that it has continued to do this for little money for over ten years, and that there is no MYSTERY connected with the removal of tastes and odors from vegetable and animal matter from water supplies, the following recent letter from the Bethel Water Commissioners will show:

BETHEL, Conn., April 28, 1901.

JOSEPH B. RIDER, C.E.,
Consulting Engineer,
South Norwalk, Conn.

DEAR SIR:—Yours received. Was glad to hear from you and to know that you are still in the filter business.

I can say that the filter is working satisfactory in EVERY respect. As I told Mr. Hatch, I should advise a double filter so one could be filtering while the other was being cleaned; this would save impure water from going into our mains while we are cleaning it. I should also advise some kind of a hard bottom, with cement walls around the bed at a height of sand bed; this would cost little and would make it impossible for water to go through anything but sand.

We CLEAN our bed in June or July each year as we get better effect from the sun in either of those months as the sun is directly over the bed, which makes the deposit dry quicker and easier to clean. We put on 4 inches of sand each year. We have taken from our bed as high as twenty-two horse loads of deposit at a cleaning, so you see we deprive the people from consuming that amount.

I have watched this system for a long time and find it easy to operate. It costs an average of $35 (thirty-five dollars) a year for sand and work in cleaning, so you see it is not expensive to handle.

We have maintained the pressure in the Borough with only one foot of WATER ON THE FILTER BED. Our pressure is just as good when using the filter as when we do not. At midnight when the factories are all shut *down we have 85 lbs.* pressure; when they are all run-

ning in the day time we have 75 lbs. at the same place; that is at O. Benedict's Hat Factory, about a mile from the reservoir and filter.

The TOTAL COST to maintain and operate the filter for the last 10 (ten) years has been $400 (four hundred dollars) and this sum included some extra work. Our population is 3,500. I think your father told us once that the daily consumption was about 200,000 gallons, but we could, in my mind, pass through the filter 300,000 gallons per day should it be required.

The filter got clogged a little once and we gave it the "back pressure" and it done the business all right; now we give it the back pressure once a year. Should you want any other data or reference, write and I will be glad to answer you, as I CANNOT SAY TOO MUCH IN FAVOR OF THE SYSTEM.

The filter is in continuous use except for one or two days each year while it is being cleaned.

We do not pay any attention to it only ONCE A YEAR.

The commissioners told me to write anything I saw fit and sign their names.

Yours truly, (C. H. Hart, for)
C. H. HART, Water Commissioners,
A. W. TWISS, Borough of
A. T. NOXON, Bethel, Conn.

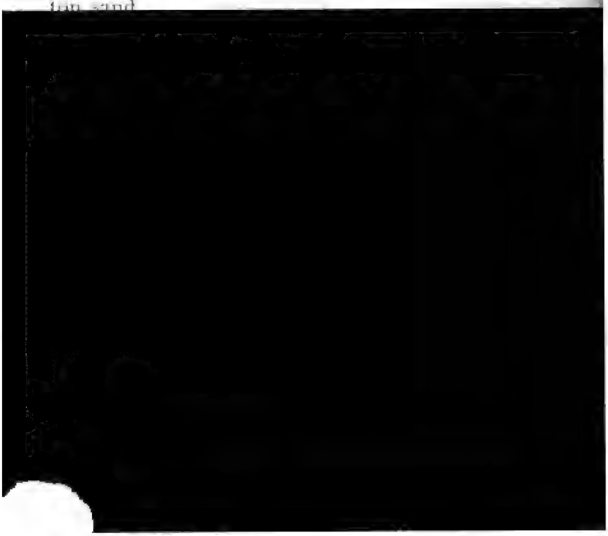
The total first cost, chargeable to filter at Bethel was	$3,000.00
The total first cost per capita was less than	1.00
The annual cost per capita for interest apc. is	0.04
The annual cost per capita to maintain and clean is	0.0114
The total annual cost for pure water per capita is less than	0.0514
or less than five and one-sixth cents.	
The annual interest account amounts to 3000 x .04 equals	120.00
The annual cost to maintain and clean amounts to	40.00
The total annual cost for pure water amounts to	160.00

The daily consumption is not less than 200,000 gallons, or 73,000,000 per annum; therefore the total cost at Bethel, Conn., for the last ten years for a water in every way satisfactory, derived from water charged as highly with vegetable and animal growths, with their tastes and odors, as any that the author has had to contend with, has been $2.19 per million gallons. This

fact, most of this amount is done within the upper one inch. The German law prohibits less than 12 inches of fine sand.

The under drains should be laid in parallel rows, with open joints, covered with fine gravel, and not a greater distance apart than depth of the bed. Spaces between and to point few inches above them should be filled with broken stone (4 inches to 6 inches above is ample). Coarse gravel, fine gravel and coarse sand should follow in about equal depth layers of from 3 inches to 6 inches each, or sufficient depth of each so that they show as distinct layers. It is good practice to have the drains on a slight grade toward the collecting well and bring the broken stone layer to a level plain; this makes the bed thicker near the collecting well at points of least distance of travel for water entering the drains and tends to give a more uniform rate of flow through all points of the bed.

The fine sand of top layer should be at least 12 inches deep, if germs of disease are in the raw water. If vegetable or animal matter or turbidity is the cause for complaint, less depth can be used if care is taken to replace sand removed after each "scraping." In one case where sand was expensive, the author obtained an average constant removal of 97.5 per cent. of organisms during seasons of "bad water" with 4 inches of top sand.



np in a *few* cubic feet of sand, stir it thoroughly h hoes; two men on opposite sides (ends) of the c; keep putting in more sand and stir it il box is about one-half full; drain off water; nove sand to the filter-bed, and repeat. If id is not obtainable or is too expensive. wash in a ilar manner material from hard-pan bank, separating coarse and fine material by water carriage and eens. The Bethel Filter was constructed of material m a hard-pan bank—not even one cubic yard was ained from any so-called sand-bank.

RATE OF FLOW.

For waters containing sewage and most turbid waters, to 3.5 million gallons per acre per 24 hours is gener- y best. For waters containing algæ growths, a much her rate, 5 to 7 million gallons can sometimes be d; in fact, with any water, the rate, within limits, is t as important as to maintain a uniform rate. Sew- has been removed from water, together with dis- e-producing germs, at a 9 million rate, but it is best keep the rate as low as possible consistent with reas- able expenditure.

ST OF ORDINARY FILTER-BEDS, USING DOWNWARD FILTRATION.

The English and Continental beds have cost from 50 to $2.50 per square foot complete. Many are cov- d to prevent ice forming over them. To cover adds average of 100 per cent. to the cost. Certain uncov- d beds in America have cost as high as $100,000 per e; this is on account of their small area and appur- ances costing nearly as much for small as a large bed. e Lawrence, Mass., Filter-bed (2.5 acres) cost $75,-), with $2.00 per day labor, or $30,000 per acre. At ual price, $1.50 per day for labor, cost would have en about $22,500 per acre complete. Rate of flow opted at Lawrence was 2 million gallons per acre day. The filter was designed to run intermittently, t there is no apparent advantage in so running a fil- . for the removal of disease-producing germs, if the v water is not deficient in oxygen. In 99 cases out 100 it is not.

f it is not necessary to build embankment or wall irely *around the proposed* filter-bed, as is the case *n it can be placed* below a dam in a ravine or valley,

[illegible]

[illegible]

[illegible]

[illegible]

extent; this fact must not be overlooked in design :ation plants.

ıer uses of air are explained under "Upward Filn."

Mechanical Filtration.

1895, the author reported at Philadelphia, Pa., rel- to the purification of the City supply. The *'d* said in part, editorially, as follows: "The *'d* has already commented upon Engineer Joseph ider's report on a municipal water filtration sys- to the effect that this well known expert has pre- d to the City the FIRST DEFINITE PLAN of ırification of the drinking water of the community," etc.

that report filter-beds constructed outside the res- rs were advised, and at greater cost another plan, ıd for beds was not available, of constructing them e reservoirs, using air as at Nantucket, and UP- FILTRATION, allowing a chance, as Henry nann, M. D., Ph. D., of the State Board of Health, the author, had determined, for an average of over :r cent. of the matter in suspension to be deposited edimentation, without coming in contact with the (See "Upward Filtration.") Because of the rt (copy of which will be sent to those desiring it), s been assumed by many that the author is not in r of Mechanical filtration. It was distinctly stated mechanical filters could do good work, but that did not always do it, and that for Philadelphia would not be most economical even if they did do ect work at all times. Philadelphia has since ›ted and is constructing filter-beds. Since that time, old type of pressure filter has been fast going out se, and the "open gravity type" (then not so highly ected) is now the standard, and is without doubt ıg splendid work for many municipalities. As now structed and operated, they can either alone or in bination with aeration and sedimentation, purify any :r that can be made pure by filter-beds, aeration and mentation.

'ithin a short time certain makers have adopted the em of perforated air pipes for agitating the sand used by the author at Nantucket.

ıe action of sulphate of alumina (alum) is des-

cribed under "Swamp and Colored Waters;" it is about the only coagulent used to any extent. Its amount will vary from a fraction of a grain to 5, or even more grains per gallon, with a highly turbid water purified without subsidence in separate basin. At Norfolk, Va., with a water at times quite turbid and highly colored with vegetable matter, 2.5 grains per gallon were used during a test with perfect satisfaction, giving results as follows:

Albuminoid ammonia removal, 94 per cent.

Color removal, 93.6 per cent.

Bacteria removal, 99.5 per cent.

At Norfolk, advantage of 12 to 15 hours subsidence is obtained in 5 million gallon basin or reservoir. The capacity of the plant is 8 million gallons per day and cost complete about $13,000 per million capacity, or with money worth 4 per cent., the interest account amounts to $1.42 per million gallons filtered. The cost to operate the plant, furnish coagulent and other expenses, except repairs, sinking fund and interest are estimated by the Superintendent and Chief Engineer at $5.47. We therefore have a total $6.89 per million gallons as the cost at Norfolk, exclusive of repairs and sinking fund. The situation at Norfolk is no criterion, however; each case must be considered alone; local conditions will vary every item, and as full information will be given for the asking by the Filter companies

ater; if it did or would, all air valves would
it the lowest points on a pipe line.

vill not, of its own accord, flow upward
r; if it did all wells would flow and reservoir
ild have to be tied to the bottom.

n flowing downward with sufficient velocity
h it such loose material as may be attached
nnel or medium through which it flows; if it
"blow-offs" on a pipe line should be situated
iest points.

erial deposited by water, can generally again
d by it, especially if the current used in re-
n the opposite direction and assisted by grav-
neglect of this fact that has caused so many
failures, such as the Queen Lane Reservoir
lphia. River silt is frequently mistaken for
fact that clay, if moved at all has been
a body, and not particle by particle, should
remembered.

nearly eight years ago, the author, as pres-
engineer of a small water company, had to
ith a turbid water in a climate severe enough
) to form 12 inches to 14 inches of ice. Up-
tion was not, nor is it now popular; 1st, be-
Rivers Pollution Commission Reports are to
that it is not a rational method; 2d, because
n, Del., and other places, with rapid rates of
tried it with small success. When proposed
hor, as a possible solution of the problem at
iia, such experts as George W. Rafter, Wm.
and others refused to pass an opinion, or
l it. Henry Leffmann, M. D., Ph. D., of the
nia State Board of Health, on the other hand,
nany years experience with Schuylkill water,
mitted that no principle involved in the pur-
f a water supply had been changed, simply
ater was made to flow in a direction opposite
stomary direction in most designs of filters,
advantage of sedimentation, when the water
ng slowly upward to the filter-bed could not
by experiments, but was feasible and practi-
ie face of such opposition, fearing he was in
ie author contented himself by continuing his
s, and for eight years has noted the practical

results. At the place above mentioned, there was constructed a circular basin 24 feet in diameter and 10 feet nearly in depth. Four feet above the bottom a flooring of 2 inches by 4 inches lumber was laid (2-inch side down) with ¾-inch openings between timbers, on top of this was placed a few inches of gravel, and next 18 inches of clean building sand. Proper valves and connecting pipes, furnished, regulated and discharged the supply. The water entered the bottom, through a butterfly valve, the float to regulate which, was in chamber connected with water over filter. Water passed upward at rate not exceeding 30,000 gallons per day. More than 100 analyses have shown an average removal of 75 per cent. of the matter in suspension in the water before it reached the bottom of the filter-bed, all of which was accomplished in the sedimentation chamber, four feet under the filter, away from action of wind. It then passed upward through the sand to the pure water chamber, or section above the sand, and from here was discharged at a uniform rate to receiving well from which it passed to the consumer. To clean the filter, a waste gate connected with extreme bottom of the basin was opened and filtered water passed backwards (downwards) at a rate ten times as rapid as the upward rate of filtration, thoroughly cleaning the bed and removing matter from the bottom deposited by sedimentation. It

e operated from three to five times as long
:aning than the Downward flow beds with the
r, where every particle of matter in suspen-
: water helps to form a blanket of considera-
on top of the bed, through which all water
: that it is no more trouble to clean the bed
o open an ordinary valve, and that the water
cleaning the bed, will seldom exceed 1 per
.e consumption, or amount purified; that the
s seldom, if ever, greater than the generally
tandard filter-bed; that a filter so construct-
operated downwards, if at certain seasons it
e, and the sedimentation chamber used as a
away from the light. Knowing the results
onstantly throughout a period of eight years
emical and biological standpoint, the author is
o substantiate his opinion, in the face of any
by designing and constructing such plants
nteeing the results from every standpoint to
d.

ays best to imitate Nature when possible, and
to have well established natural laws and phe-
ssist, rather than have them in opposition. In
ied sedimentation, upward filtration and aer-
sand agitation when necessary method this
y done, while all are in direct opposition in
'ARD filter-bed method.

On page 347, the use of alum and air for
ification in 1846 is mentioned. In that year
s of Norwalk river were made suitable for
coloring purposes by a prominent Hat Man-
by the use of alum and air. John Rider, a
engineer of considerable note, had to do with
uction and operation of the plant which was
entire success for several years or until for
easons the plant was removed elsewhere. Wil-
Rider, C.E., constructed purification plants
and alum prior to 1872. Others have done
no doubt, but the above instances are cited
the fact that the author can show by papers,
s possession, that their use in water purifi-
his family at least) dates back three genera-
y *one desiring* to use air or alum certainly

have the right to do so, without fear of such law suits as have been often threatened, provided the method of application does not infringe on certain patents.

WATER WORKS FROM A FIREMAN AND INSURANCE COMPANY STANDOINT

A fire is never "beyond control" where there is a good fire department with proper equipment, ample quantity and pressure of water.

Conflagration is always the direct result of neglect to provide one or more of the above essentials.

In 1900, Apalachicola, Florida, paid the penalty of refusing to provide any method of protection by losing her business centre; about a year later Jacksonville lost ten million dollars or approximately $500 per capita by fire; a sum sufficient to have provided every place in the state needing it, with up-to-date water works and fire department equipment, many times over.

GENERAL DATA, TEMPERATURE, ETC.

Wood chars at 350 degrees Fahr.

Wood takes fire at 550 degrees Fahr.

Water changes to steam, in open atmosphere, at 212 degrees Fahr.

Steam changes to hydrogen and oxygen gases at 1470 degrees Fahr.

Oxygen supports combustion; lack of it will put out a fire.

Hydrogen in burning makes the hottest of fires and

Table No. 198

OR OF FLAME AND CORRESPONDING TEMPERATURE.

D denotes a temperature of about 977 degrees. Fahr.
ERRY denotes a temp. of about 1470 deg. Fahr.
ANGE denotes a temp. of about 2000 deg. Fahr.
HITE denotes a temp. of about 2370 deg. Fahr.
ST IRON melts at a temp. of about 2000 deg. Fahr.
ASS melts at a temp. of about 2400 deg. Fahr.
EEL melts at a temp. of about 2550 deg. Fahr.
ROUGHT IRON melts at a temp. of about 2900 deg. Fahr.
IRE BRICK fuse at a temp. of about 4000 deg. Fahr. and above.

ATER WORKS, IN THE ORDER OF THEIR RELIABILITY AT A FIRE.

Gravity works are considered most reliable; they are pposed to ALWAYS "be ready" while a pumped supply ay not be.

Next best, is system pumping to adjacent distribu-on reservoir of ample capacity to supply in case of pairs or "break down" at the pumping station. The servoir should not hold less than one week's supply us reserve sufficient for six hours' supply for great-t probable fire; this reserve should always be ready for stant use and the reservoir so constructed that even hen it is being cleaned or repaired, one section of it ill retain the above reserve.

Next best, pumping to large standpipe of sufficient ight to give ample pressure.

Next best, pumping to a small standpipe of sufficient ight to give ample pressure.

Next best, pumping direct into the mains without ndpipe or reservoir.

All pumping systems should be at least in duplicate h ample boiler and pump capacity in each unit to e the full maximum daily load plus fire streams with- "forcing."

With large distribution reservoir close to business tre. all fires can be drawn for a day or so at a e, provided two mains of ample capacity connect with the distribution system. Never have both nps apart or all boilers disconnected at the same e; *keep one set* ready "to start" within a few min- *after an alarm* of fire.

[illegible] shor [illegible]

[illegible] The [illegible]

ssure to be delivered at fire. Cast iron mains and rals are most reliable and popular.

teel mains are "rusted out" rapidly by most waters. ner waters, especially many of the Pacific slope have le effect. Where transportation is expensive or iron h priced, they often can be used to advantage.

Cement lined pipe lines are not in favor with insur-e companies presumably because several main lines, Massachusetts and elsewhere, have been ruined by htning. Many old cement lined mains were made h poor cement and just as little of it as was possible use and make the sand remain in place, resulting in ndemnation of such pipe lines in general. As now de by reputable makers they are certainly giving sat-action in numerous municipalities. The cement lin-g prevents tuberculation (see Table No. 136) and ns the original area of the pipe and discharging ca-city are maintained.

For this reason it would not be a bad idea to coat the side of cast iron mains with cement as laid.

Pipes made of wood are little used for main lines or erals intended for fire protection and domestic uses; nen properly made such pipe, in the eastern and cen-al states is nearly as expensive per foot laid as cast on of the same diameter. The best place for such pipe under the "lead kettle" melting lead for joints of st iron main to take its place. For large conduits in uthern California and elsewhere that are to supply ater for irrigation as well as other purposes local ood can often be used for less money than iron or eel on straight work, using wrought iron or steel on arp curves. Such conduits are best constructed in e trench as the work proceeds, if above 18 inches in ameter.

STRIBUTION SYSTEMS, EFFECT ON INSURANCE RATE.

Small laterals increase insurance rate.

Four inch pipe should not be laid in a business centre in location liable to be occupied in near future by siness blocks.

Six inch in the minimum size of pipe that should be d in a business centre.

Eight inch costs little more and "will pay for itself" every *fire of few hours'* duration.

Feed all laterals from both ends when possible; this

under ordinary conditions will double the delivery available at a hydrant or hydrants connected to it. When this cannot be done lay at least, next larger size main than the one contemplated.

In irregular laid out cities loop around the outside with ample size main and connect it at every possible place with cross connecting laterals.

If the city is large and laid out in squares or blocks run at least 12 inch parallel mains every second or third street and cross connect them with 8 or 10 inch laterals, of themselves connected at every intersection. Burlington, N. J., population about 8,000, has its business centre connected by 16 inch main with the standpipe and pumping station a few blocks or squares away, thus giving efficient fire protection reducing friction to a practical minimum and carrying standpipe pressure with little loss to the hydrants.

Philadelphia, Pa., on the other hand has dozens of miles of 6 and 8 inch lines in locations where nearer 30 and 48 inch ought to have been laid. Boston has 30 per cent. of its distribution system 12 in.; New York has slightly less. If there is a difference of opinion as to which of two sizes to lay, choose the largest; tuberculation will reduce its capacity soon enough (see table No. 136.)

The difference in insurance rate in favor of an 8 inch

ıe best hydrant is none too good; they should all ı by turning wrench in same direction. They should ›pened and closed SLOWLY; under ordinary condis as many seconds should be used in closing the rant, at a uniform rate as there are pounds static ısure at the hydrant. If less time is consumed, .ter hammer" will result. (See "water hammer.")

ʼo hydrant should be allowed to "freeze up;" do not ays blame the drip because it has; investigate and if it is properly drained.

n New England hydrant branch should be covered at ıt 4 ft. at gutter line. In the North West, 5.5 ft. or re.

Iave adjacent hydrants on opposite sides of the ɜet, so that at a fire all will not be on the "wrong e."

ʼour-way hydrants are not as desirable as more two three way ones.

Never use less than a six inch connection for two ı three-way hydrants.

Each hydrant branch in locations where building line ɔn or close to the street line should have independent te, otherwise falling walls may snap off the hydrant ndpipe allowing a six inch stream to run to waste and reduce pressure that other streams will not be effece. The common method is to put the gate as close the hydrant as possible; it is the author's practice to t them close to the main pipe or lateral; this allows om for accumulation of debris over and near the hyʼant and saves loss of time necessary to remove it ːfore stream can be shut off.

An average hydrant set costs much less than 100 feet hose. Hose rapidly depreciates in value (see hose) hile hydrants do not. Hydrants are therefore cheaper an hose; increasing their number allows more prompt d efficient work at a fire. One at least should be ced at each intersection of streets and at least one ʼut one half way between; if more than one between, ce them equidistantly. Study probable location of ře fires, and place hydrants so that delivery given ler *fire streams* can be concentrated on it from the ıt. *sides or rear*, through short lengths of hose; if

possible for reasonable expense, through 250 or 300 ft. of hose.

Flush hydrants are not from any standpoint preferable to regular standard pattern. Ice and snow and other difficulties off-set any advantage they may have.

See to it when ordering from different makers, that top and nozzle nuts and threads per inch on couplings are the same from each and that they are EXACTLY what is in use in your place. If constructing New Works have all correspond to standard of near by city, so in case of trouble you can "help each other out."

VALVES OR GATES.

Have all turn in the same direction to open; serious loss has been caused through neglect of this precaution when placing "second orders."

Inspection should be frequently made to see if all are open and if they can be closed when necessary. They should be uniformly placed on street lines at the same distance out from the fence, building line or curb. In winter the boxes should be kept free from ice and snow.

Do not be afraid of a little extra expense for brass stems, nuts, etc. Fifty cents extra cost, average, for gates on laterals will insure their being ready for use when needed; if "iron to iron" is used, they may or may not work. Often more thousands of dollars worth of property may be in jeopardy than it would take cents to insure proper working and quick repair of the controlling gates.

The liberal and proper use of relief valves will reduce if not prevent excessive "water hammer." Air and vacuum valves should be placed at all high or necessary points and be open when filling or emptying the pipe line; otherwise compressed air may "throw the pipe out of the trench" or partial vacuum collapse some weak portion of the pipe system.

HOSE.

The most reliable hose to hang inside of a building for use therein only in case of fire is UNLINED LINEN. It should be tested every six months out-doors thoroughly air dried and replaced. When water is first turned on, the hose will leak a little but the material soon swells enough to stop it.

For all around fire department service, double jack-

ber lined cotton hose is best. For rough usage and h pressures use tripple jacket.

The jackets should be made water proof by wax and n or other treatment. It is best to have the jackets ven in opposite directions; when so woven the hose ds to "kink" less under pressure.

Two and a half inch is standard size for general use. ree inch and larger sizes are used in connection with ge steamers, fire-boats, water-towers, high buildings, ., but with high pressures require mechanical appli-ces to take up the reaction, properly direct and control stream.

The life of the best hose depends on the quality of rubber lining fully as much as on rough usage of ket and care taken to dry it after fires. It averages th moderate care from five to ten years; depreciation erages 10 cents per lineal foot or $5.00 per length r annum.

High Buildings should have external standpipe sia-ese connections at the street level. This saves time getting lines of hose up stairs, especially at night, hen elevator may not be running and insures more rompt work by the fire department. Such 6 inch or 8 nch standpipes cut insurance rate about 5 per cent.

SIAMESING.

Six lengths, 300 ft. of hose, will absorb about 50 per ent. of the working pressure at the hydrant; this loss an be reduced to a practical minimum by siamesing wo lines from the hydrant to a point one length back om the nozzle, giving one length or 50 feet of free ngle line. If siamesed as above, the loss of pressure ll be about one-fourth that of a single line over the ne distance.

One steamer pumping into a siamesed line will de-r more efficient fire stream at nozzle than two mers. pumping one into the other and a single line r the same distance.

00 feet of hose siamesed offers no greater resist-e than 250 or 300 feet of single line of same diam- using same nozzle and pressure at hydrant.

STEAMERS.

n average Steam Fire Engine can deliver 500 gal-s per minute under pressure sufficient at end of reas-ble length of hose lines, to give two fair fire streams,

this is at the rate of 720,000 gallons per day (see page 266.)

An average large steamer with 3 inch hose can deliver 1,200 gallons per minute or one 1½ in. and one 1¼ inch streams or with two short lines of hose, two 1¼ inch streams.

Where municipality has grown rapidly, many mains are often too small for efficient use at a fire; as a temporary expedient pending laying of mains of adequate size, cisterns holding 25,000 or 30,000 gallons can be constructed alongside or at the end of small mains and be fed by them.

Steamers taking water from the cisterns can thus do efficient work for one or two hours in locations where delivery of pipe line is deficient.

Detroit has used with success 7,000-gallon cisterns.

Fire Boats.

Eight and ten inch fire mains from the water front back for a distance of one-half mile, with good fire boat and connections furnishes a most efficient and economical auxiliary method of fire protection for the larger business districts of many municipalities. Except in freezing weather it is best to keep the mains full of water. Have hydrant or hydrants open when filling or emptying the mains, unless relief valves are used as they should be.

If salt water is used flush the mains with fresh water after the fire.

The first use of a fire boat is to protect the water front, but inasmuch as the boat can protect for the distance back above mentioned, without extra cost for boat equipment, the mains should be laid, thus reducing the necessary cost of the land equipment. Have electric signal connection between hydrants and fireboat.

Pumping Stations for Fire Protection.

If situated at the water front of a city, and connected with business district by large mains, with high buildings equipped with standpipes such stations are of undoubted benefit and paying investments. They reduce the necessary cost of pumping stations for domestic supply and industrial uses and the necessary system of distribution. Independent fire systems of water works are destined to supersede present methods in the large cities and in addition to the above advantages, less pr

sure can often be carried on distribution mains for domestic supply; cost of water purification is reduced while the fire mains can deliver under a pressure that would be prohibitive, bursting fixtures, etc., if carried even at times of fire in the mains of system furnishing the domestic supply.

NOZZLES.

One and one-eighth inch nozzle is best for all around use and under 40 to 50 lbs. working pressure at nozzle will throw the solid portion of a 225 to 300 gallon stream to a height of from 60 to 80 feet or to the top of a four story building. One and one-quarter inch nozzle will give about 20 per cent. more.

Where electric wires are numerous care should be taken to use an insulated nozzle or handles; otherwise "short circuiting" or grounding of the electric current, which will follow the stream, to the nozzle and through the pipeman may kill or injure him.

Table No. 199

APPROXIMATE DISCHARGING CAPACITY OF NOZZLES.

Two 11-16 nozzles about equal to "one" 1 in. nozzle.
Two ¾ nozzles about equal to "one" 1 1-16 in. nozzle.
Four ¾ nozzles about equal to "one" 1½ in. nozzle.
Four ⅝ nozzles about equal to "one" 1¼ in. nozzle.
Two ⅞ nozzles about equal to "one" 1¼ in. nozzle.
Two 1 in. nozzles about equal to "one" 1⅜ in. nozzle.
Two 1⅛ in. nozzles abouot equal to "one" 1⅝ in. nozzle.
Two 1¼ in. nozzle about equal to "one" 1¾ in. nozzle.
Two 1⅜ in. nozzle about equal to "one" 1 15-16 in. nozzle.
Two 1½ in. nozzle about equal to "one" 2⅛ in. nozzle.

PRESSURE AND FIRE STREAMS.

Eighty lbs. working pressure (not static) at hydrant is best for effective work; this will give about 40 to 50 lbs. at nozzle at end of five lengths or 250 feet of hose under average conditions, (crooks and turns) at a fire

The static pressure at a hydrant is not a guide as to what can be done at a fire. The main pipe lines and laterals should be large enough to deliver quantity used at a fire without great loss of head in friction.

Too small a main could easily reduce a static pressure *of 100 lbs.* to 20 lbs. or less working pressure, th *making useless* the water works for fire protection.

Tables No.'s 120 to 131 will show the size of pipe line necessary to discharge the quantity of water desired at a fire as given in the eighth column of each table, without loosing any more of the total head or fall than will leave ample for working pressure. The amount lost is given opposite in the 2nd, 3rd and 4th columns in feet and in the 5th and 6th in pounds pressure; by subtracting it from the total (in the same unit) the working head or pressure is at once given.

Working pressure x 1.5 equals fair average height to which streams can be projected; 40 lbs., 60 ft.; 60 lbs. 80 ft., etc. The rule does not hold good beyond an average of 100 lbs. pressure for small nozzles; at that point the streams begin to "strip" and as pressure is increased, height of projection is actually reduced, as shown by the following Table.

Table No. 200

SHOWING EFFECT OF INCREASING PRESSURE BEYOND PROPER LIMIT IN REDUCING HEIGHT OF FIRE STREAMS.

5/8 in. stream,	43 lbs. pressure,	height stream 75 ft.
5/8 in. stream,	86 lbs. pressure,	height stream 100 ft.
5/8 in. stream,	130 lbs. pressure,	height stream 75 ft.
5/8 in. stream,	150 lbs. pressure,	height stream 50 ft.

If size of nozzle is increased instead of pressure; for 200 ft. head, 86 lbs. pressure we have, for height of streams, from 3/4 in. nozzle, 116 ft.; 1 in., 137 ft.; 1 1/4 in., 150 ft.; 1 1/2 in., 158 ft.; 1 3/4 in., 166 ft.; 2 in., 169 ft., or increasing pressure to say 130 lbs. we can have 2 in. stream, 230 ft. high. Increasing pressure to 150 lbs. we can have 1 1/4 in. stream nearly 200 ft. high, 1 1/2 in., 220 ft.; 1 3/4 in., 240 ft., and 2 in., 250 ft. high or five times as high as a 5/8 in. stream can be thrown with same pressure.

The question of maximum height of fire streams, with various sizes of nozzles and pressure has been thoroughly treated by Thos. Box, C. A. Ellis and others; enough is pointed out above, however, to show the necessity of adapting nozzles to the pressure in use. The proper size is determined best by practical test, that should be made by every new department and old ones as well if they have not been, using every size nozzle *with* varying lengths of hose.

At least 3,000 gallons per minute should be provided for fires in a business district of a small city, but regardless of the size of a city, a compact "nest" of wooden buildings, large factory or large tenement house in nine cases out of ten ought to be protected by having ready for instant use, eight to ten streams. In designing works never provide less than

3 streams for small villages
5 streams for 5,000 population.
10 streams for 10,000 population
15 streams for 20,000 population
18 streams for 30,000 population
20 streams for 50,000 population.

Hydrant Tax or Rental.

To provide for Fire Protection, increases the cost of the distribution part of a water-works from 35 to 60 per cent. over sum necessary to provide for domestic and industrial uses. Extra cost for reservoirs, pumps, etc., will vary with local conditions. The interest on this extra cost plus equitable portion of expense to maintain and operate ought to be collected by hydrant tax. To so collect, makes each property owner benefited pay his share whether he is a water consumer or not. If not so collected the water consumers must pay a greater rate and indirectly pay for benefits given their neighbors (in reduced insurance) that do not help support the system by paying water rent. A certain sum must be raised annually to pay interest and cost to operate and it is but fair that it be equitably distributed, putting any surplus in sinking fund for bond redemption or for extensions. The smaller the place supplied, the more important is it that the above suggestions be carried out, because as total cost of works is decreased the proportion expended for fire protection is increased.

The following Table as condensed from John R. Freeman's Tables of fire streams, in the author's experience, has been found conservative; the distance that the fire stream can be projected as given, mean distance reached by good effective SOLID stream and not the much greater distance covered by "drops." The pressures given are those indicated by gauge while stream is flowing from the nozzle at end of hose coupled to hydrant or steamer *in the ordinary way.*

Table [No. 3]

[illegible]

Hammer" is the pressure indicated by the
a stream of water flowing through a pipe
bination of lines is suddenly stopped. The
re indicated is a measure of the work per-
stopping the stream. Water being nearly a
d, the entire length of the pipe line or lines
voir, stand pipe or pump performs work or
ately, every square inch of the interior sur-
pipes must resist the blow in pounds per
that is indicated by a gauge connected to
on of the line or lines.

r or "water hammer' is independent of the
ure and its intensity increases as the time
he aperture decreases.

in by example, the following experiments
e author are given.

x and two-tenths feet of 1-inch pipe were
with a reservoir on such a grade (about 10
ll) that the pipe discharged 1.26 pounds per
held 13.25 pounds of water.

city was 3.44 feet per second; if the water
d in one second, the work performed on an
05454 square feet (area of one inch pipe)
been 13.25 x 3.44 equals 45.53 pounds. Now
to the above there was another column of
ng that had to be stopped because the water
inches deep in the reservoir over the inlet.
we must add .453 pounds x 3.44, or 1.55
ch added to 45.58 pounds gives 47.138 pounds
nmer," on an area of 0.7854 square inches
ne inch pipe). Therefore on an area of 1
, the effect was 60 pounds. By actual ex-
is is found to be the case.

the same line when greater or less time
econd was used in closing the outlet, the
pressure agreed with the actual pressure re-
the gauge, within a small percentage. The
robably due to inaccuracy in noting the time.
ne above mentioned a pressure of 260 pounds

In several experiments with lateral lines of small pipe, it was noticed that the recorded pressure at the center of the line of pipe, was greater than at the outlet, or at point near main line. In one case, for instance, on a one-half inch pipe line 250 feet long, the pressure recorded at either end was 240 pounds (four times static pressure); at the middle the pressure recorded was 300 pounds (five times static pressure). The author is unable to account for this fact.

It can be shown that if a fire stream of 150 gallons per minute is stopped flowing in one second from a hydrant connected with 30 ft. of 4 inch pipe to a 12 inch main 23000 ft. long, the water hammer or blow will be about TWO TONS per sq. inch. If the static pressure is 65 lbs., the time used in closing the hydrant ought to be in seconds 4000 (two tons) divided by 65 or about 60 seconds in order that the effect of water hammer would not be much noticed. See "hydrants" page 367. Quick closing fixtures are a necessity in many places where water is used. It is best however to use meters and slow closing fixtures whenever possible, and in so doing waste will be checked as efficiently as it can be accomplished by quick closing fixtures alone.

Hydraulic Rams.

Depend on blow or "water hammer" caused by suddenly stopping a stream of water in the "drive pipe" to

EMBANKMENTS.

QUICK METHOD OF COMPUTING CONTENTS.

In making monthly estimates of work completed, or final estimates in light "cut and fill" road or other similar work, instead of reading each depth of cut or fill from the profile or cross-section paper or taking it from your notes, the average depth can be obtained quickly as follows.

Take a long strip of paper; place one end of it at grade or other line at Sta. 0 and mark point (1) on the paper a distance from the end equal to the depth of cut or fill as given on profile or cross-section paper at Sta. 0. Move strip to Sta. 1, putting point (1) at grade or other line and mark point (2) a distance from (1) equal to cut or fill at Sta. 1; proceed likewise to the end of cut or fill as given on the profile or cross-section paper paying no attention to the actual amount of each at any station. Measure the summation of depths as marked off on the strip of paper by the vertical scale of the profile or cross-section paper used and divide the amount by the number of stations; the result is the average depth. Compute area of cross-section having this average depth and multiply it by the total length of the work. The method will give results near enough for all practical purposes and save much time and liability of error in calculation.

The author has tested the method on many miles of road and other work and found it to give results in error too small for consideration.

Where cross-section is of quite irregular shape, much time will be saved by cutting them out as drawn on cross-section paper, weighing them on analytical balances and comparing weight with that of a unit area cut from the same paper. Likewise the area of Reservoirs, water sheds, or any other area can be determined within less than one percent. (if balances are of good make and sensitive) resulting in a saving of much time, and giving results more accurate than the usual method of division of the area into triangles; finding their area and adding that of the remaining irregular sections *as computed* by rule given on page 53. For *Prismoidal formula*, etc., see page 77.

FOUNDATION FOR EMBANKMENTS, "

The foundation for any embankmen
ground should be cut in the form of ste
each of which should dip downward fr
the riser of the next highest step; suc
tendency to slide or spread and in case
bankment is to hold back water, it assis
the water following the bond between t
earth. As one expressed it "if there is
hates, it is a right angle, or to turn a

SETTLING OF EMBANKMEN

A liberal allowance must be made; it
most zero to 33 or more per cent. See
page 180. It is always best to experim
terials as they are placed from day to
known quantity and subjecting it in a
method of treatment it is receiving in t
as near as it is possible to do so. Suc
quently save disputes as to "quantity pl
final estimate. This is especially true
rolled embankments are constructed. I
age of five cu. yds. of material in ba
in puddle embankment.

HIGHWAY AND R. R.

For cost to construct embankments,
Embankments should be made of co

.e it should be left in such a manner that the
of water on it after completion of the dam
: sufficient to permit percolation into, through
t so as to weaken or ruin the structure as a
ach 32 ft. in depth of water exerts one net
re on each sq. ft.; water under such pressure
: way through voids, crevices, etc., quite in-
the human eye and apparently tight. In the
xperience in expert cases he has met those
ıg obtained an ample supply of well water
tain strata, expected water to remain in reser-
:ructed of material taken from the same stra-
nstructed upon it without proper preparation
:ightness.

ossible for reasonable cost perishable or por-
MUST be removed to a line at least 10 ft. be-
wn-stream side of centre puddle or core wall
firm and water tight foundation into which
cut parallel trenches under the entire length
bankment; such trenches ought not to be a
stance apart than 0.5 x height of dam or em-
at centre; they should be 4 or 5 ft. wide and
same depth if in a good or fair foundation.

have trench cut just inside (under embank-
inside foot of slope.

ation is "questionable" increase the depth ac-

ıoved perishable earth, etc., can be placed in
m toe of slope or saved for a top dressing for
ost makes any earth porous; therefore remove
to point below that which has been effected

.TIONS IN POROUS SOIL, QUICK-SAND, ETC.
ently happens that a dam must be placed in
where a porous sand, gravel or quick-sand
ed must be contended with; to excavate to
om" would cost in many cases more money
ıvailable for the project; in others it is often
impossible to do so. In such cases the fol-
thod as used with success by W. B. Rider,
nany difficult locations, especially in Cali-
l often make of the porous material an effi-
rete foundation."

[illegible] diameter [illegible]
[illegible] conditions
[illegible] centrifug
[illegible] shows [illegible]
[illegible] adjacent
[illegible] the sheet
[illegible] penetration. [illegible]
[illegible] and [illegible]
[illegible] wall of [illegible]
[illegible] less dens

[illegible] EMBANKM

[illegible] material.
[illegible] layer [illegible]

When haul is too great for wheel-barrows, (generally barrows cease to be economical if haul is over 300 feet) use carts and begin filling at one or both ends of dam; as the work progresses, cover the fresh layer with a line of 16 ft. plank, dumping off the end and immediately spreading so that top of the layer is not more than four inches above the water, move the end planks back and forth from edge to edge of bank covering the entire width of embankment with the layer as work proceeds, this saves work in shoveling after material is delivered. When driving on the planks they will "take on" a wave motion, stirring in a beneficial manner material under them. Embankments built by this method will seldom settle a noticeable amount; or with good material not over one inch for each ten feet in height of bank.

MATERIAL FOR EMBANKMENTS OF DAMS.

Hard-pan or Clay mixed with gravel is best, but if they cannot be obtained loam and gravel or loam and sand, properly mixed will make a tight bank.

The proportions of each are best determined by ascertaining the amount of voids in the gravel or sand by methods given under "Pavements and Roads," see pages 185, 186, 187 and 193, or as given under Table No. 194, and adding a liberal amount of clay or loam in excess of that determined by the analysis. Average bank gravel or sand contains much clay or other binder, often sufficient in itself to make a tight bank. As a rule however every fourth or fifth load of material taken to make the embankment should be CLEAR clay or loam, free from perishable material, grass, etc., and it should be thoroughly mixed with the earth from the bank, before or at the time it is placed in the embankment.

No embankment can be made absolutely tight; even the best of clay contains from 10 to 15 per cent. of voids that rolling or puddling will not materially reduce; if however they are reduced to say from 8 to 12 per cent. the embankment will be practically impervious to water, as molecular attraction will then be sufficient to prevent percolation.

Other things being equal, a heavy material should be selected; *a properly* puddled bank, especially if the

binder is of clay, will be nearly equal in weight to that of limestone masonry.

Clay alone should not be used; it is liable to slip under action for water; muskrat and other holes made in it do not "close up," while if it is used as a binder only, they do.

Slope of Dam.

The inside slope of a dam ought not to be less than 1½ to 1, even when the best of embankment material is used in construction and it in turn properly paved or covered with rip-rap. Unless it is protected by rip-rap or other paving, wave action will in time reduce the slope to from 4 or even 10 to 1, depending on the material used. It is the author's practice to use inside slope of 1.5 to 1 for small distribution reservoirs filled by pumping or gravity, when located on top or side of hills away from a stream. For small reservoirs of heights up to 30 or 40 ft., inside slope of not less than 2.0 to 1 or when possible 2.5 to 1. For large reservoirs, exposed to "long sweep" of the wind, or reservoirs requiring greater height of dam than 40 ft. he uses inside slope of 2.5 or 3.0 to 1. For down-stream slope, 1.5 to 1 is ample in all cases, unless surplus material must be removed in excess of that required, in which case it is placed in down-stream embankment, forming a berm or increasing the slope to 2 or more to 1.

The greater the slope, the more permanent will be the dam.

Rip-Rap Paving.

Made of random stone is better than a smooth paving; ice will simply lift a few of the outside stone of such paving, leaving the most of it intact. In excavating in bank for the material for embankment, as a rule sufficient stone can be obtained for the rip-rap and it is cheaper to cart them than to leave them in the way of operations at the bank; no large stone should be allowed in the up-stream embankment; their proper place is in the rip-rap, or down-stream bank. Rip-Rap paving on small dams should not be less than 12 inches thick; 18 inches is better. Where wind has a great sweep toward it, increase its thickness one foot for each mile of sweep in excess of one mile. *Don't try to build too rapidly by laying stone "flat;" they will not stay in place; put them on edge.*

Springs.

If springs are encountered in excavating for foundations, do not try to stop their flow with one or several loads of concrete, puddle or other material; it cannot in nine cases out of ten be done and done well. Cover over the spring, with substantial masonry and lead its waters through pipe to or below the down-stream slope.

If flow of spring is checked it will often in finding another outlet exert through the accumulated water so checked, in the strata, a pressure sufficient to endanger the stability of the dam.

Core Walls.

Cement and stone are too cheap to longer permit of the construction of dams in locations where their destruction would cause loss of life and property, without their use in a core wall. Muskrats will make holes; frost will lift earth embankments; but muskrats cannot bore holes through masonry and frost will not lift a properly tapered core wall.

The thickness of core wall ought to be at least 2 ft. on top; 18 inches will do, but it costs just as much money per lineal foot to build an 18 inch wall as it does a two foot wall on account of the greater amount of labor in fitting stone in an 18 inch wall, so that none will reach through its entire width. Have top of wall one or two feet below top of bank and taper it, well coated, and smooth, to below the frost line or to point 4 to 6 ft. below the top; at this point it should be at least 2.5 ft. thick; 3 ft. is better. From this point to foundation, wall should be constructed in vertical sections each about 5 feet high, and at least six inches thicker than the section next below.

Foundation should be broad enough to distribute the weight so that pressure per sq. ft. will not exceed 4 tons.

Grout.

It is almost impossible to build a "cemented wall" across a valley or anywhere else and have it absolutely tight; a stone once placed in cement mortar if effected by the slightest jar never again (even though the cement has not set) will take as good a bond; the result is that it will leak, though perhaps slightly, at every place *where a stone* was so disturbed. By building up *the faces of the wall* in mortar, in horizontal section

About 40 per cent. of the more than 15 structed from plans of W. B. and J. B. from designs of W. B. Rider) were mad dled up-stream embankment, centre core and down-stream embankment puddled t line 8 ft. below and parallel with the core

So far as known, all are "water tight" ing the functions intended.

Where suitable stone cannot be procur crushed cobble or other stone can often b concrete core wall. It will give satisfacti erally not cost more per cu. yd. than ce wall, and from every standpoint is prefer

Over-Flows or Waste Weirs.

If Government tables giving flood disc stream are not available and a series of we meter measurements extending over a per has not been made, the best way to deter proximate flood discharge is, after enquir living along the stream, to ascertain the a of the bottom of the stream at or near location of dam and from the drift wood dence along its banks of "high water m mine the probable fall of the surface of t

[illegible]

[illegible]

[illegible]

rater at centre of height of dam, the centre line of sure for section one foot long at centre of height lam is perpendicular to the slope through the point t a depth of 14 feet. Likewise the centre line of sure is found for any other depth or slope. This for puddled or rolled embankments should always the base up-stream from the centre line of the dam.

PRESSURE ON A VERTICAL RECTANGULAR WALL

Never construct vertical rectangular walls of over or seven feet in height to retain water when it can avoided; the same quantity of masonry placed in a tered wall, as hereinafter explained, will be much onger; in other words, to resist a given pressure, it l cost less in masonry to construct a battered wall.

The total pressure of water on a vertical wall of unim height, and thickness, assuming the water to exa pressure along its entire length and height, as in ilter bed partition or gate chamber, when there is no ter on one side of the wall equals in NET TONS,

Length x square of height of wall x 0.0156, or

Area x height of wall x 0.0156, or per foot in length wall, we have square of height of wall x 0.0156..(b)

The centre line of pressure given by (b) is in a horntal direction (perpendicular to the face of the wall), ough the point P at two-thirds the depth of the water wall.

If the wall is not of uniform height, find its centre gravity and proceed as above indicated or divide the all into several sections, finding the total pressure on ch section and then their combined resultant. It is ldom necessary to find the total pressure except at int of maximum height of dam; sections of wall at her points should be made for a given height, same as entre section on horizontal line opposite.

In the case of a solid cemented wall acting as one ass, the force can be considered as acting through the oint P, situated at centre of width of the rectangular all at height equal to one-third total depth of water foundation. This horizontal force evidently acts with lever arm equal to the height of P, and as in the case f wind pressure on standpipes (see page 260) tends to ush the wall over. Its MOMENT will be, in NET TONS,

Area x square of height x 0.0052, or per foot in ength,

... pounds per cubic fo...

... x 10375....

EXAMPLE.

... 100 feet; height, ...

... of pressure on a ...

... Net Ton (cent...

... the total pressure

... length ... per ...

... Moment of Pressure

... per foot of length 17...

... of wall at 6 feet

... of the masonry to

... per tons, or

... of the strain of ...

... per foot and is ...

... remaining in place; in

... under the wall,

... increase this exces...

... wall at 8 feet, we

to 1 we obtain Thickness equals square root of quare of height x 0.277) ....(e)

pplying equation (e) to above wall we have for the quisite thickness 7.9 feet. The difference of 0.1 feet om assumed width of 8 feet, being on account of neg- ct of decimals beyond third place.

When good grouted rubble or other first class mas- ury is used, and placed on a practically impervious undation, it is the author's practice to simply make e width of a rectangular wall to sustain pressure of ater on one side equal to ONE HALF ITS HEIGHT. This ves a safety factor of about 1.7 to 1, and as yet he s never had a wall fall or rupture. With poor work, wever, the width must be increased.

RESSURE ON INCLINED SURFACE OF DAMS OF EARTH OR MASONRY.

It takes just as strong a dam to hold back one acre as it does ten thousand or more acres of water of me depth at dam.

With slope of up-stream side of dam, it directly sup- orts simply the triangular section of water above it; ot up the pond, but vertically over the slope. The eight supported per foot in length of dam equals in ET TONS, with

4 to 1 slope, height squared x 0.0625.
3 to 1 slope, height squared x 0.0469.
2 to 1 slope, height squared x 0.03125.
1 to 1 slope, height squared x 0.015625.
0.5 to 1 slope, height squared x 0.0078.

For any other slope to dam, the weight per foot in ngth supported equals in NET TONS, area of section of ater above the slope x 0.03125 ....(f)

HORIZONTAL COMPONENT

the pressure of this weight will evidently be as ven by equation (b), assuming it to act on a vertical ane; this force tends to slide the dam in a horizontal rection.

VERTICAL COMPONENT

the weight, acts in a vertical direction, through the int P and tends to hold the dam in place, or coun- ract such vertical tendency as there may be to "lift e dam" by water reaching the foundation. In amount is equal in NET TONS to

The horizontal component x secant of
Width of dam x depth of water x 0.03

UPWARD PRESSURE

tending to lift the dam will depend e
amount of and the rapidity with which
strata under the embankment or masonry
cannot exceed in [illegible] tons per foot in le

Width of dam x depth of water x 9.0

If the dam was well constructed of go
foundation was properly prepared, or if
[illegible] masonry or other first class materi
pressure will be insignificant in amount.
[illegible] be amply allowed when it equals 25 p
[illegible] equation [illegible]. For safety many
[illegible] that it will be equal to 50 per cent. o

The author in several instances ha
[illegible] through the core wall of
[illegible] stream toe. In each instance when
[illegible] construction, the accumulated
[illegible] taken care of with a common d
[illegible] concluded that held in the d
[illegible] embankment there was no
[illegible] pressure due to the pressu

entire length and up to the centre line (at least) e pipe line. The pipes were not strong enough to ·, between piers, the weight of bank and water e. Instead of placing pipe lines from in- ; vertically or nearly vertically over each r through a dam, it is always best to place n up the side slope from each other, a suf- nt distance apart to get the requisite or desired erence in elevation between intakes; in this way it ossible to place the lines on solid masonry on firm ndation through the dam; at or near the lower slope y can be connected together with cross connecting : with proper valves on it and each line so that any of the lines can be used without the others.

'ipe lines laid through a core wall and through the embankment, are liable to snap off at the face of wall as true as if cut with a knife, on account of 1 the slightest setting of bank, and thus bringing the re weight above on the pipe; it acting as it does, on :ver arm, is generally sufficient to rupture the best ieavy pipe.

: is the author's practice to place masonry as above- itioned and in addition to build up at each joint icient to enclose it. This helps to prevent water owing the pipe line. It is a hard matter to make a it joint between the coal tar on the pipe and cement; :n possible, after masonry is within a half inch or of grade and pipe is in place, pour in hot asphalt :oal tar to form the bond between pipe and mason- Do not delay covering pipe, as expansion by sun's · will ruin a cement joint, while it can do much in- · to other kinds.

one of the above equations take cognizance of the that when a horizontal force is applied to a struct- the structure tends to slide as mentioned under rizontal Component."

he ratio of the force necessary to slide a body to veight is called the

COEFFICIENT OF FRICTION

r safety in making calculations relative to mason- 'alls, it is assumed that the mortar does not prevent stone sliding on another when a horizontal force is ied. Ordinary masonry offers a resistance to slid- on *masonry of* about two-thirds its weight. In ad-

[illegible]
[illegible] JOC [illegible]
[illegible]
[illegible] with [illegible]
[illegible]
[illegible]
[illegible]
[illegible] with. [illegible]
[illegible]
[illegible]
[illegible]
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[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

ıation (j) we have,
ıns (weight of wall per lineal foot) plus 0.818 equals 7.88 tons. Deducting 2.34 tons for up-essure and assuming coefficient of friction at have 3.66 NET TONS; this is in excess of 3.51 : amount of the horizontal component, but not to insure safety if the upward pressure is as assumed; increasing top width to 3.5 or 4., or vidth to 12 feet will give requisite margin.

S OF PRESSURE AND WEIGHT OF MASONRY

LEVERAGE

gh the point of application of the forces, draw the parallelogram of forces; the diagonal rep-; the resultant ought to cut the base well with-ɔe of the masonry, or not to exceed one-half ınce from the horizontal projection (p) of the : gravity of the section of masonry to the "toe," 1 from the (p) toward the "toe."
ıount in tons is directly given by scale.

WIDTH OF WALLS.

y are to retain water on either side to top of, r to top of the wall, as in the case of partition c., and are of greater height than 10 ft., make vidth equal to 0.66 x height of wall for a top 4 feet. If top width is made less than 4 feet the bottom width so that the area of the adopt-ın equals area of same height of wall on above f less than 10 feet in height make bottom width 0.66 x height for top width of not less than 3 less than 3 feet in top width, increase bottom as to give an equivalent section as above men-

OF WALLS WITH PRESSURE AT ALL TIMES ON ONE SIDE.

s case put from 75 to 90 per cent. of total batter le (down stream) face.
ght of wall is less than 20 ft., make bottom : least 0.7 x height for top widths of one-fifth ıt except when one-fifth height is less than three which case make top width three feet.
is made less than three feet, increase bottom *proportion* as above mentioned.

For wall 20 ft. in height make bottom width equal to height x 0.75 for top width of 0.25 x height. If top width is reduced increase the bottom width in proportion as above mentioned.

For greater heights than 20 ft. reduce the top width by one per cent. for each 10 ft. in height above 20 ft. and increase bottom width the same amount up to 150 ft. in height. For heights above 150 ft. increase bottom width by 1.5 per cent., but make top width 18 ft. for all heights, above 150 ft.

EXAMPLE.—Dam 100 ft. high. Required its top and bottom widths.

100 ft. less 20 equals 80 ft. or 8 x 10 ft., therefore for top width we have 25 per cent. less 8 or 17 per cent. of height. 100 x 17 equals 17 ft. the top width required.

Increasing bottom width by one per cent. for each 10 ft. in height above 20 ft. or 8 per cent. more than 0.75 given in the rule, we have 100 x 0.83 equals 83.0 ft. the bottom width required.

For dams exceeding 50 ft. in height, put fully 85 to 90 per cent. of the total batter on down stream side; when possible have waste weir elsewhere than at the dam.

For dam 150 ft. high we have, by same method, top width of 18 ft. and bottom width 130.5 ft.

For dam 180 ft. high we have, top width of 18 ft. and bottom width of 165 ft.

For dam 200 ft. high we have, top width of 18 ft. and bottom width of 189 ft.

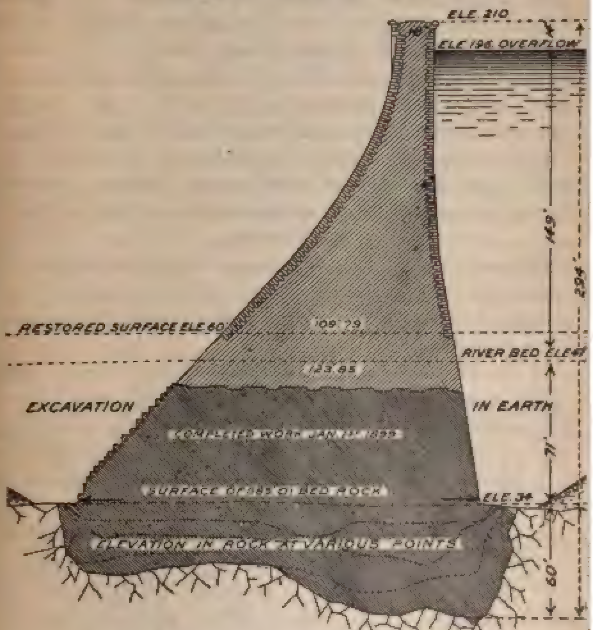
All of the above refer to first-class cemented masonry.

CURVED MASONRY DAMS.

The limits of this work prevent detailed discussion of this subject. Fig. 35 shows the New Croton Dam (solid masonry). It is of good form. Its section is in close agreement with that proposed by Prof. Rankine for Reservoir walls of great height. At 150 ft. depth, width proposed by Rankine is 122.22 for top width of 18.74 ft. Width for uniform battered wall, by rules just before given for height of 150 ft. it will be noted, gives top width of 18 ft. and bottom width of 130.5 ft. or but 7 per cent. greater bottom and 4 per cent. greater top width than given by Rankine for curved section.

For less height of dam than shown in Fig. 35, use same face curve from top to point a distance below equal to height of dam and reduce top width to adopted width, but not to an amount that will make effective area of section less than just before given under "Width of Walls."

FIG. 35, NEW CROTON DAM.



MASONRY GATE OR INTAKE CHAMBERS.

Cemented masonry forming the walls of intake chambers placed in reservoirs is very liable to be displaced or the cement bond injured by action of ice. With ice adhering to the walls with a grip of 40 lbs. to the sq. in. ,and sudden rise in water as in the spring, part of masonry with gate house above is liable to be moved on the "breaking up" of the ice and be deposited elsewhere in the reservoir as in a case brought to the author's attention. Ice shock and thrust frequently cause such structures to leak to such an extent that they ar useless for the purpose of keeping out the water wh in need of repairs to gates, etc., at the bottom.

The author having had considerable trouble with such intakes has abandoned their construction in favor of the method mentioned under "Pipe Lines on Piers," simply constructing plain copper screen intakes, set in masonry but easily removed and replaced (even at high water) in their slides. This leaves nothing but plain straight pipe lines through the dam, and if well laid on masonry there is no reason for repairs or attention. At down stream side, opposite each line put on bolted cap to facilitate inspection of line if ever desired. To those owning this work and interested, blue prints of connections, etc., will be forwarded for $1.00. By stating exact conditions, proper selection of prints can be made.

When pipe lines cannot be placed on the slope, use centre core wall for one side of gate chamber; protect the up-stream side with ample puddle embankment.

Ice Thrust.

Water at the instant of change into ice increases in volume about 8 per cent. and if confined exerts an expansive force or pressure of about 15 tons per sq. inch. (See page 252.)

If the entire volume in a reservoir one mile long "froze over" instantly the dam at one end would have to move down-stream about 40 feet to make room for expansion. As a matter of fact water freezes gradually and when a resistance such as a dam is encountered in one direction, expansion cannot overcome it unless the

ice to the sides is sufficient, the ice surface will no longer move upwards to provide for expansion and as the water refuses to be compressed, the wall must rupture or force water out of the confined space to make room for the increase of 8 per cent. in volume. With thick ice, unless masonry dam is sufficiently battered on inside face, there is danger of rupture.

The best preventative is a puddled embankment with proper slope, on up-stream side of wall.

KNUCKLE-JOINT.

The greatest danger from ice in a reservoir is from the "knuckle-joint" formed at or about the water level after a pond has been drawn down subsequent to freezing over. On again raising the water the inclined portion of ice, one end of which will be adhering to the dam, tends to push it over by the force exerted at the crack or joint; the amount of the force does not admit of exact calculation, but the author can recall of more than a dozen instances where the force was sufficient to rupture 6, 8 and 10 ft. solid masonry walls. A moderate batter will reduce the danger.

RETAINING WALLS.

It would be quite useless to here discuss the subject theoretically for "Jack Frost" would step in and upset any calculation. Below is therefore given simply a few notes that in a general way outline the author's practice.

WIDTH OF WALLS.

For ordinary retaining walls of Dry masonry or cemented masonry made of small stone such as can be handled without a derrick, make width of base (at ground line) from four-tenths to three-sevenths the height. If wall is of first-class CUT stone or cemented rubble masonry of heavy stone, the bottom width, except in case of quick-sand strata back of wall, can be reduced to height x 0.33.

SURCHARGED EARTH.

If the earth retained by the wall is higher than the top of it and has a slope of not less than three-fourths or one to one backwards from the back face of wall increase the bottom width of wall as given above by 5 per cent. for each 10 per cent. increase in total height of bank retained.

If retained earth is of uniform consistency throu out the year so that it will "stand" on a nearly ver

bank on a steep slope or even 1 to 1 if not too ex-
isive and fill in the space with coarse gravel or other
ous material that drains rapidly and is but slightly
hen dry) effected by frost. Place it in horizontal
ers as the wall is constructed. Construct "weep
les" through the wall as often as may be necessary or
y every 10 ft. and in addition lay an open joint tile
ain parallel with and just back of the wall. This
ethod reduces to a minimum disturbance by frost.

BATTER OF BACK FACE.

It should not be battered except the top portion as ove mentioned, but stepped in uniformly; this gives chance for better stability by having the wall hold rectly the weight of a portion of the backing.

In the construction of several important walls, the thor has constructed them up to just below the maxi- um depth of frost of proportions above mentioned. At is point the thoroughly packed gravel backing was veled off and the thickness of the wall increased back- ards into or toward the bank sufficient to allow a tter of at least 45 degrees toward the front face of all at the top, leaving requisite width of top thickness. he backing in freezing lifts easily along such a batter ithout any injury to the wall; the method increases it slightly the cost of important or high walls. Cir- mstances may be such that less masonry can be used an has been above suggested; but the author's expe- ence in such matters is, that it pays to be on the safe ide and success is not certain if the amounts are much educed.

It is cheaper to put in 10 cu. yds. extra in the first lace than to risk danger of falling walls, and finally ebuild.

Walls of coal sheds or bins must be of same thick- ess for a given height as walls for retaining water; e thrust being about the same. Cellar walls in addi- on to sustaining thrust of earth must carry weight. icrease width of foundation so as to properly distri- te it, if necessary. See page 261.

HEATING ROOMS AND BUILDINGS.

The determining factors are,

1st. Amount of cold or fresh air entering per minute or hour.

2nd. Amount of heat to be supplied to replace losses by conduction, convection and radiation.

The general rule is to design to heat up to 70 degrees Fahr. from air at zero. As less than zero temperature frequently occurs in a large section of the States, many heating plants ought not to be designed on the above basis.

One cubic foot of air is the unit used. From data under Table No. 146 we have that with barometer at 30 inches and temperature of 60 deg. Fahr., one pound of air occupies a space of 13.06 cu. ft. also that the volume of a given weight of air is proportional to its absolute temperature, we therefore have the proportion given below to determine the volume of one cu. ft. of air at zero degrees Fahr.

520 is to 460 so is 13.06 cu. ft. to the volume required; from this we obtain the volume of 1 lb. of air at zero degrees Fahr. to be 11.55 cu. ft.

Therefore 1 cu. ft. at zero weighs 1 divided by 11.55 or 0.086 lb.

The specific heat of a body is the quantity of heat necessary to raise its temperature one degree Fahr. compared with that necessary to raise an equal weight of water one degree. The specific heat of air is, at constant pressure, 0.24. It therefore takes 0.086 x 0.24 or 0.0206 B.T.U. (heat Units) to raise the temperature of 1 cu. ft. of air one deg. Fahr. (For amount in other units see "STEAM AND FUEL NOTES."

To heat air from zero to 70 deg. Fahr. will require 70 x 0.0206 or 1.442 B.T.U. per cu. ft. of air.

Each cu. ft. of air heated from zero to 70 deg. according to data under Table No. 146 will expand and at 70 deg. occupy a space of 1.15 cu. ft.; each cu. ft. at 70 deg. will weigh 0.086 divided by 1.15 or 0.074 lb.

According to Wolff, the loss by transmission in B.T.U. (heat units) per hour per sq. ft. of surface exposed to lower temperature than interior of the building or room per degree difference in temperature is as given in condensed form in the following Table.

Table No. 202

UNITS LOST PER SQ. FT. PER HOUR PER DEGREE DIFFERENCE IN TEMPERATURE, BETWEEN INSIDE AND OUTSIDE OF THE FOLLOWING BUILDING MATERIAL, ETC.

(Condensed from Wolff.)

BRICK WALLS.

ches thick	0.68	8 inches thick	0.46
ches thick	0.32	16 inches thick	0.26
ches thick	0.23	24 inches thick	0.2
ches thick	0.17	32 inches thick	0.15
ches thick	0.13	40 inches thick	0.12

nary doors	0.41
nary single window	0.78
nary double window	0.52
nary single skylight	1.12
nary double skylight	0.62
nary Fire proof construction, as flooring,..	0.12
nary Fire proof construction (floored over) s ceiling	0.15
nary Wooden beam construction, as flooring,	0.08
nary Wooden beam construction, planked over or ceiled, as ceiling,	0.10

› use the above table,

H equal the amount of heat lost, or that which ust be replaced if room is to remain at constant mperature.

A equal the area of the "heat transmitting" surce in sq. ft.

B equal the loss by transmission in heat units B.T.U.) per sq. ft. of outer surface per hour for ach degree difference between inside and outside mperature in degrees Fahr.

I equal inside temperature to be maintained.

O equal temperature outside of and adjacent to the om or building to be heated.

'e then have,

quals A x B x (difference between I and O) or in e case of zero outside and 70 deg. Fahr. inside we ve,

quals A x B x 70.

ke value of B from above or, in certain cases, the wing *table as given* by Peclet, will be found of asnce. *See also* text following Table No. 204.

Table No. [illegible]

[illegible]

[illegible]	[illegible]	[illegible]	1.4[illegible]
[illegible]	[illegible]	[illegible]	0.89
[illegible]	[illegible]	[illegible]	0.77
[illegible]	[illegible]	[illegible]	0.75
[illegible]	[illegible]	[illegible]	0.27
[illegible]	[illegible]	[illegible]	0.5
[illegible]		[illegible] average	0.74

Table No. [illegible]

[illegible] Heat Conduction [illegible] Heat Units [illegible]

[illegible]	[illegible]	[illegible]	0.3
[illegible]	[illegible]	[illegible]	0.6
[illegible]	[illegible]	[illegible]	1.3
[illegible]	[illegible]	[illegible]	6.6
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	233.
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table No. 206

Heat Units (B.T.U.) Absorbed or Emitted per Sq. Ft. per Hour by Hot Water Pipes.

Mean Temp. of Heated body, pipe, etc.	Temp. of Air and Walls.	Units of Heat per sq. foot per hour.				
		By Contact.		By Radiation.	By Radiation + Contact.	
		Air quiet	Air moving		Air quiet	Air moving
70	70	0	0	0	0	0
80	70	5.04	8.40	7.43	12.47	15.83
90	70	11.84	19.73	15.31	27.15	35.04
100	70	19.53	32.55	23.47	43.00	56.02
110	70	27.86	46.43	31.93	59.79	78.36
120	70	36.66	61.10	40.82	77.48	101.92
130	70	45.90	76.50	50.00	95.90	126.50
140	70	55.51	92.52	59.63	115.14	152.15
150	70	65.45	109.18	69.69	135.14	178.87
160	70	75.68	126.13	80.19	155.87	206.32
170	70	86.18	143.30	91.12	177.30	234.42
180	70	96.93	161.55	102.50	199.43	264.05
190	70	107 90	179.83	114.45	222.35	294.28
200	70	119.13	198.55	127.00	246.13	325.55
210	70	130.49	217.48	139.96	270.49	357.48

Table No. 206 A

Heat Units (B.T.U.) Absorbed or Emitted per Sq. Ft. per Hour by Steam Pipes.

Mean Temp. of Heated body, pipe, etc.	Temp. of Air and Walls.	Units of Heat per sq. foot per hour.				
		By Contact.		By Radiation.	By Radiation + Contact.	
		Air quiet	Air moving		Air quiet	Air moving
210	70	130.49	217.48	139.96	270.49	357.48
220	70	142.20	237.00	155.27	297.47	392.27
230	70	153.95	256.58	169.56	323.51	426.14
240	70	165.90	279.83	184.58	350.48	464.41
250	70	178.00	296.66	200.18	378.18	496.84
260	70	189.90	316.50	214.36	404.26	530.86
270	70	202.70	337.83	233.42	436.12	571.25
280	70	215.30	358.85	251.21	466.51	610.06
290	70	228.55	380.91	267.73	496.28	648.64
300	70	240.85	401.41	279.12	519.97	680.53

Table No. 207.

HEAT UNITS (B.T.U.) PER SQ. FT. OF HEATING SU[R]FACE PER HOUR NECESSARY TO HEAT 1 CU. FT. OF AIR FROM AND UP TO VARIOUS TEMPERATURES.

Temp. of external air.	TEMPERATURE OF AIR IN ROOM.							
	40°	50°	60°	70°	80°	90°	100°	110°
0°	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262
10°	0.604	0.806	1.007	1.208	1.409	1.611	1.812	2.013
20°	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771
30°	0.192	0.385	0.578	0.770	0.962	1.155	1.345	1.540
40°	0.000	0.188	0.376	0.564	0.752	0.940	1.128	1.316
50°	......	0.000	0.184	0.367	0.551	0.735	0.918	1.102
60°	......	......	0.000	0.179	0.359	0.538	0.718	0.897
70°	......	......	......	0.000	0.175	0.350	0.525	0.700

Area in sq. ft. of radiating surface at vari[ous dis]tances from boiler furnished supply through [various] diameters of pipes with

STEAM PRESSURE OF ONE LB. PER SQ. I[N.]

Diam. of steam pipe in inches.	DISTANCE OF RADIATOR FROM BOILER I[N FEET.]					
	9	64	100	225	324	400
	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
¾	366	137	109	73	61	55
1	752	282	225	150	125	112
1¼	1312	492	393	262	218	196
1½	2074	777	622	415	345	311
2	4244	1591	1273	848	707	636
2½	7436	2788	2231	1487	1239	1115
3	11702	4388	3510	2340	1950	1755
3½	17206	6452	5161	3441	2864	2580
4	24042	9016	7212	4808	4007	3606
4½	32292	12109	9687	6458	5382	4843
5	42013	17505	12604	8402	7002	6302
6	67564	25337	20260	13513	11260	10134
7	97372	36514	29211	19474	16228	14605
8	136209	51078	40862	27242	22701	20431
9	182966	68608	54886	36591	30492	27443
10	237973	89240	71392	47594	39962	35696

STEAM PRESSURE OF 10 LBS. PER SQ. [IN.]

Diam. of pipe in inches.	DISTANCE OF RADIATOR FROM BOILE[R]					
	9	64	100	225	324	400
	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.
¾	146	55	44	29	24	22
1	301	113	90	60	50	41
1¼	529	198	158	106	88	79
1½	832	312	249	166	139	124
2	1707	640	512	341	284	256
2½	2982	1118	894	596	497	447
3	4706	1765	1412	941	784	706
3½	6919	2596	2075	1384	1153	1037
4	9146	3429	2743	1889	1524	1371
4½	12966	4862	3889	2593	2161	1944
5	17006	6377	5101	3401	2834	2550
6	26628	9985	7988	5325	4438	3994
7	39150	14684	11747	7831	6526	5873
8	54679	20504	16404	10936	9113	8202
9	73659	27622	22098	14731	12276	11049
10	96496	35811	28648	19099	15916	14324

Schumann suggests the following data relative to Connection pipes and Coils.

Table No. 208

SIZE OF CONNECTION PIPES FOR COILS IN HOT WATER HEATING FOR TOP FLOOR.

For 60 sq. ft. of coil surface use ¾ inch pipe.
For 100 sq. ft. of coil surface use 1 inch pipe.
For 175 sq. ft. of coil surface use 1¼ inch pipe.
For 250 sq. ft. of coil surface use 1½ inch pipe.
For 600 sq. ft. of coil surface use 2 inch pipe.

IN STEAM HEATING.

(Direct or indirect radiation.)

For 25 sq. ft. of coil surface use ¾ inch pipe.
For 40 sq. ft. of coil surface use 1 inch pipe.
For 80 sq. ft. of coil surface use 1¼ inch pipe.
For 160 sq. ft. of coil surface use 1½ inch pipe.
For 250 sq. ft. of coil surface use 2 inch pipe.

Increase the sectional area of pipes about 15 per cent. for each floor toward basement. For heating basement use next lower commercial size of pipe than those above given. For proper size of branches use Table No. 143.

BOILER CAPACITY REQUIRED

Will vary greatly, depending not only on all the conditions before mentioned but upon the transmission power of the radiating surface and the efficiency of the boiler.

Approximately we can say, when making rough estimates, that the ratio of Boiler Heating Surface (For boiler tubes see Table No. 175) to radiating surface of 1 to 10 will cover average conditions; with good radiating surface the ratio may be as low as 1 to 6 while with poor radiating surface as high as 1 to 15 or 18. Again small buildings require proportionately more boiler capacity than that necessary for large ones on account of the relatively larger proportion of exposed surface.

With 15 lbs. steam pressure, the ordinary smooth unpainted pipe will transmit about 400 heat units (B.T.U.) per sq. ft. per hour, giving slightly greater efficiency in a vertical than horizontal position. Ribs or corrugations reduce the radiating efficiency about 1 per cent. for each 1.5 per cent. of the radiating surface corrugated or *75 per cent. of* surface corrugated reduces efficiency *to about 200 heat* units per sq. ft. per hour. In hot

[illegible]

ꝶIDER'S SANITARY NOTES

ɔpyright, 1901, by Joseph B. Rider, C.E.)

SEWAGE

nount of dissolved and suspended organic and : matter in sewage varies with the habits of ɔle; with the per capita water consumption; kind of manufacturing industries of the mun- ; with the amount of infiltration of ground to the sewers; with the quality and porosity of and compactness of population per unit of ered. In the same place it varies from day to uring the first year a system is in operation, filtration of ground water is considerable from aminated for years, the amount of organic and : matter is generally high; with no increase in ɔn it gradually decreases but in most munici- ɔoth density of population and water consump- capita increase after sewer construction, thus ing, more rapidly than the above counteracting ecrease, the quantity of dissolved and suspend- r in sewage per unit volume.

sual to find the amount greater each year. Ac- to the Mass. State Board of Health, the sew- awrence, Mass., contained in parts per 100,000 wing.

Table No. 209

SEWAGE OF LAWRENCE, MASS.

monia	1.86 parts per 100,000.
buminoid ammonia	0.66 parts per 100,000.
Albuminoid ammonia ...	0.29 parts per 100,000.
: Albuminoid ammonia .	0.37 parts per 100,000.
....	5.73 parts per 100,000.

ɔove amounts by Table No. 195 to 4.81 grains . gallon or 0.0816 ounce per cu. ft.

n consumed was 3.44 parts per 100,000 while ria per cu. centimeter numbered 871,000. The es the average results of four years observa- a manufacturing city, in which much of the

[illegible] average [illegible]

[illegible] Bremen [illegible]

[illegible] analysis:

[illegible] suspended [illegible] matter.

[illegible] . . . . [illegible]

[illegible] . . . . [illegible]

[illegible] average American

[illegible] at the

[illegible] disposal plants would

[illegible] grains of dissolved

[illegible] Where street drainage

[illegible] materially [illegible]

[illegible] sugar 100 grains [illegible]

[illegible]

[illegible] organic matter [illegible]

[illegible] average [illegible]

[illegible]

[illegible] The inorganic

[illegible] similar [illegible]

[illegible] organic and [illegible]

Table No. 210

Each 100 grains or one-fourth ounce, nearly (0.229) per cu. ft. of dissolved and suspended matter equals

22.9 parts per 100,000

229. parts per million.

Parts per million x 0.001 equals ounces per cu. ft.
Parts per 100,000 x 0.01 equals ounces per cu. ft.
Table No. 195 will also be found convenient.

Effect of Turbid Waters on Amount.

Under "Turbid Waters" page 339 we have that the Mississippi River contains an average of 350 parts per million or by above table 0.35 ounce per cu. ft. In high stage of river, 2300 parts per million or 2.3 ounces per cu. ft. or nearly 10 times the above mentioned basis of 100 grains or one-fourth ounce per cu. ft.

Where such a water is used as a water supply and later have added to it the sewage of a municipality, it is evident that the amount to be taken care of by a sewage disposal plant per unit volume will be many times that shown by the Lawrence analysis. Each case must be considered apart from all others and the above facts have been mentioned, simply to emphasize the importance of not being guided by precedent.

After due allowance has been made for the normal amount in the uncontaminated soil of the neighborhood, chlorine and nitrogen are indicators of the amount of sewage contamination. Frequently, especially foreign analyses are expressed in part by giving the organic nitrogen per 100,000 or million parts while others are given in part by giving the albuminoid ammonia. Prof. Drown suggests as the result of his experience with many waters that when the Wanklyn and Kjeldahl methods are used to determine the amounts, that the organic nitrogen will be about double the albuminoid ammonia, for the same water or sewage.

Excrements

In average sewage make up about one-half the total contamination.

In pounds per capita per annum according to Rafter and Baker it amounts to that given in the following table for the average mixed population of men, women, boys, *girls, etc.*

[illegible] water.
[illegible] organic matter.
[illegible] nitrogen.
1.29 phosphoric acid.
[illegible] potash.
[illegible] lime.
[illegible] magnesia.

SEWERAGE

[illegible] and air are conduci[illegible]
[illegible] especially the latter. [illegible]
[illegible] drought and is father of [illegible]
[illegible] not possible in any com[illegible]
[illegible] removal of the [illegible]
[illegible] animal economy and their [illegible]
[illegible] decomposition. Th[illegible]
[illegible] dry, at least free from [illegible]
[illegible] A wet soil is not he[illegible]
[illegible] humidity, if it was all [illegible]
[illegible] sick and hunches [illegible]
[illegible] measure.

A dry soil directly reduces death [illegible] conditions through the free circulation [illegible] of the air, that destroys the organic m[illegible] [illegible] existence

oper sewage disposal, and ventilation go hand in .nd; one without the other can do much, but all work-g together for the general welfare is best and have :ver failed to reduce the death rate of a community here adopted and given requisite care and attention. ondon's death rate was nearly three times as great :fore their adoption. Other places show even better sults.

QUANTITY OF SEWAGE.

It is quite useless when designing to make refined lculations based on the per capita water consumption; mount used on WASH DAY, etc., as advised by certain ithorities. With an efficient water works superinten-ent, the per capita consumption may be 50 gallons to-ty and next year his lax successor may permit 100 gal-ns to be used. Much of this may reach water courses ithout entering the sewers. Manufacturing uses then ay be more or less; again the uses in a manufacturing :ction may be ten times as much per capita for the opulation contained on the area as in another section f the same city or like the lower section of New ork, have a per capita sewage discharge 300 times as reat, when based on the permanent population, as hen it is correctly proportioned among those occupy-ig the section during business hours.

Such portions of a municipality should be considered part from others.

A trench for a 6-inch costs just as much as one for an -inch sewer. The difference in cost for pipe is sel-om over four or five dollars per 100 feet or with a ouse every 25 ft. of sewer containing 5 persons the xtra cost is but 20 to 25 cents per capita. Likewise ie difference in cost between any two sizes is small :r capita when based on its carrying capacity; hence in any instances refinements as to hourly flow, maximum ow, sewer gaugings, etc., are out of place when the erage system without sewage disposal is under con-leration. When sub-drains are not laid about 20 r cent. of total flow will be sub-soil water entering e sewer; hence the importance of sub-drains to re-ce amount of sewage to be purified at disposal plant. From the general character of the place, use judg-:nt as to the direction of future growth and plan your iin sewers accordingly.

[illegible]
[illegible] the time and there
[illegible] the average business [illegible]
[illegible] the consumer [illegible] the rest of it to [illegible]
[illegible] times the average
[illegible] excess [illegible] where [illegible]
[illegible] the upper
[illegible] to allow [illegible]
[illegible] such
[illegible] consumption per [illegible] should
[illegible] the work of [illegible]
[illegible] Water might [illegible]
[illegible] reasoning [illegible] disagreeable
[illegible] giving [illegible] equivalent
[illegible] amount is running
[illegible] gallons per capita
[illegible] water [illegible]

Table No. XX

[illegible] per Day [illegible]

[illegible] Equals

[illegible] per [illegible] per capita
[illegible] per [illegible] per capita
[illegible] per [illegible] per house
[illegible]

the amount of storm and roof water reaching

Table No. 213

ONE INCH PER HOUR RAINFALL

EQUALS

	gallons per minute from one sq. mile.
.54	gallons per minute from one acre.
.39	gallons per minute from 1000 sq. ft. of roof.
039	gallons per minute from 100 sq. ft. of roof.
	cu. ft. per minute from one sq. mile.
	cu. ft. per minute from one acre.
9	cu. ft. per minute from 1000 sq. ft. of roof.
39	cu. ft. per minute from 100 sq. ft. of roof.

also page 266 and Table No. 191.

age Continental practice provides for level sec-n average of 2.5 cu. ft. per second storm water each acre; for steep sections, about 4.25 cu. ft. cond. Many American Engineers provide for cu. ft. per second from an acre or for less than CH PER HOUR rainfall as given in the above table. fall in the States frequently is greater than one er hour, but in the great majority of cases such arrive after protracted drouth, and if catch bas-properly trapped, and the system of pipe lines is ly designed, the surplus water at such times in municipalities can be carried for the necessary inutes, generally, by the gutters, without causing n the sewers sufficient to rupture them. It will aper to repair streets after an occasional rain of um precipitation than to pay the interest on the ary extra thousands to provide for carrying ex- amounts of storm water. In larger cities, and n others it must be provided for either by sepa-ains or otherwise.

ngineer of good judgment based on practical ex-ce can do more toward arriving at a correct de-ation of the amount of storm water to be pro-for in any certain section of a municipality by tion than would be possible by consultation of all ta published relative to coefficients to be used various conditions. For this reason it is con-l quite useless to discuss the matter theoretically. engineer should not be afraid to ask questions; t *all possible* about "high water" marks in streets,

[illegible]

[redacted]

at has accumulated since a preceding storm, and d of an objection results in a decided advantage proved health of people living adjacent to it.

DISCHARGING CAPACITY OF SEWERS.

r discharge of large circular or egg-shape sewers formulae given on page 273.

r discharge under pressure if conduit is large use ulae on page 194, or if not more than 4 ft. in diam., es No. 120, etc.

r discharge of all sizes of vitrified pipe conduits sewers under any practical conditions not under sure, use the following tables.

ble No. 214 is based on Kutter's formula and has verified by several hundred experiments by the or. As first issued it is in use by more than 5000 tary engineers and others; also by many colleges ughout the country and so far as the author is n, they also have found it to agree with actual re-s on flat or at upper end of steep grades.

able No. 215, also based on Kutter's formula, has introduced to give the discharge of the larger s of vitrified pipe now giving such popular satisfac- taking the place of brick sewers, stone road and way culverts, etc.

you are compelled to lay a small sewer on such a de that the velocity of flow will be less than 150 minute as given by the tables, be sure and ar-ge for proper flushing.

he tables do not pretend to give the exact discharg- capacity of every sewer for like two boats built n identical models, two exactly similar sewers (in ign) may not glide through the water or which unts to the same thing, allow water to glide ugh them at the same rate.

n using the formula a varying coefficient of rough-s has been used based on the author's experiments; ss unusual circumstances interfere, to back up the or check discharge, the quantity given in the tables ntentionally made conservative.

efore designing by the aid of the tables, the effect cceleration due to gravity as given on pages follow- the tables, should be understood. In the author's gn for Port Chester, N. Y., and other places its *er consideration* saved several thousand dollars for *by not enlarging* main sewers every time a lateral *ed.*

Table No. 214

Table showing velocity in and capacity of Vitrified Pipe S[e]... running full,* as determined by Joseph B. Rider, C.[E.]

Copyright, 1890, by Joseph B. Rider, C. E.
(Second Edition.)

Grade Required to Produce Velocity.		Diameter of Pipe in inches.							
		6		8		10		12	
In ft. per 100 ft.	One ft. Fall in.	V	Q	V	Q	V	Q	V	Q
0.05	2000.	32.3	6.3	40.8	14.2	48.7	26.6	56.2	44.
0.0526	1900.	33.3	6.5	41.9	14.6	50.1	27.8	57.7	45.
0.0555	1800.	34.2	6.7	43.1	15.0	51.5	28.1	59.4	46.
0.0588	1700.	35.3	6.9	44.5	15.5	53.1	28.9	61.2	48.
0.0625	1600.	36.5	7.2	45.9	16.1	54.9	29.9	63.2	49.
0.0666	1500.	37.8	7.4	47.6	16.6	56.6	31.0	65.4	51.
0.0714	1400.	39.0	7.7	49.2	17.2	58.7	32.0	67.6	53.
0.0769	1300.	40.8	8.0	51.4	17.9	61.7	33.4	70.5	55.
0.0833	1200.	42.5	8.3	53.6	18.7	63.7	34.8	73.6	57.
0.1	1000.	47.2	9.3	59.4	20.7	72.2	39.5	81.4	63.
0.15	666.66	57.8	11.4	72.7	25.4	86.7	47.4	99.8	78.
0.2	500.	66.9	13.1	84.1	29.4	100.3	54.7	115.4	90.
0.25	400.	75.0	14.7	94.4	32.9	112.4	61.3	129.3	101.
0.3	333.33	82.4	16.5	103.6	36.2	123.4	67.3	141.9	111.
0.35	285.71	89.0	17.7	111.9	39.1	133.2	72.7	153.3	120.
0.4	250.	95.3	18.9	119.8	41.8	142.7	77.8	167.9	131.
0.45	222.22	101.2	19.9	127.2	44.2	151.4	82.6	178.2	139.
0.5	200.	106.7	20.9	131.1	46.8	159.7	87.7	187.9	147.
0.55	181.81	112.1	22.0	140.9	49.2	167.7	91.4	192.8	151.
0.6	166.66	117.0	23.0	147.0	51.3	175.0	95.5	201.3	158.
0.65	153.84	121.9	23.9	153.1	53.5	182.3	99.4	209.6	164.
0.7	142.85	126.5	24.8	158.9	55.5	189.7	103.2	217.6	170.
0.75	133.33	130.9	25.7	164.5	57.4	195.8	106.8	225.2	176.
0.8	125.	135.8	26.7	170.6	59.5	200.4	110.7	233.4	183.
0.85	117.64	139.5	27.4	175.7	61.2	208.6	112.8	239.9	188.
0.9	111.11	143.4	28.2	180.2	62.9	214.5	116.9	246.6	193.
0.95	105.26	147.4	28.9	185.2	64.6	220.4	120.2	253.4	199.
1.0	100.	151.4	29.7	190.1	66.4	226.3	123.4	260.3	204.
1.1	90.91	158.8	31.2	199.5	69.7	237.1	129.5	273.0	214.
1.2	83.33	165.8	32.6	208.3	72.7	247.8	135.2	285.0	223.
1.3	76.92	172.6	33.9	216.9	75.7	258.1	140.8	296.8	233.
1.4	71.43	179.2	35.2	225.1	78.6	268.0	146.1	308.1	241.
1.5	66.66	187.9	36.4	232.8	81.3	277.7	151.2	318.8	250.
1.6	62.5	191.7	37.6	240.8	84.0	286.5	156.3	325.0	258.
1.7	58.82	197.6	38.8	248.2	86.8	295.8	161.1	331.9	266.
1.8	55.55	203.2	39.9	255.2	89.1	303.7	165.6	340.2	274.
1.9	52.63	208.8	40.9	262.3	91.5	312.4	170.2	358.9	281.
2.0	50.	214.3	42.1	269.2	93.9	320.8	174.7	368.3	289.
2.1	47.62	219.6	43.1	275.8	96.3	328.2	179.0	377.4	296.
2.2	45.46	224.7	44.1	282.3	98.6	335.9	183.2	386.3	303.
2.3	43.48	229.7	45.1	288.6	100.7	343.7	187.3	394.9	310.
2.4	41.66	234.7	46.1	294.9	102.9	350.9	191.4	403.5	316.
2.5	40.	239.6	47.1	301.0	105.1	358.2	195.2	411.9	323.
2.6	38.46	244.3	48.0	306.9	107.1	365.2	199.2	419.9	329.
2.7	37.04	249.1	48.9	312.9	109.2	372.5	203.1	428.1	336.
2.8	35.71	253.6	49.8	318.6	111.2	379.1	206.8	435.9	342.
2.9	34.48	258.0	50.7	324.1	113.1	385.7	210.7	443.5	348.
3.0	33.33	262.6	51.6	329.8	115.1	392.5	214.1	451.3	354.
3.5	28.57	283.6	55.7	356.2	120.3	422.0	231.2	487.4	382.
4.0	25.	303.3	59.6	380.9	130.8	453.3	247.3	521.3	409.
4.5	22.22	321.6	63.2	404.0	138.8	480.8	262.2	552.9	434.
5.0	20.	339.1	66.6	425.0	146.3	506.8	276.4	582.7	457.
5.5	18.18	355.6	69.8	446.9	155.9	531.5	289.9	611.1	480.
6.0	16.66	371.4	72.9	466.5	162.8	559.1	302.7	638.2	[illegible]

(Table continued on next page.)

* "Running full" means when discharge is maxim[um] when depth of flow is 0.9 × the diameter, approxim[ately]. V means velocity in feet per minute, and Q the [dis]charge in cubic feet per minute, when it is maxim[um].

Table No. 214—Continued

wing velocity in and capacity of Vitrified Pipe Sewers when g full (continued), as determined by Joseph B. Rider, C. E.

to fe- ... ie all)	Diameter of Pipe in inches.							
	18		20		22		24	
	V	Q	V	Q	V	Q	V	Q
	76.5	135.2	80.	1/6.6	88.8	234.5	94.7	297.6
	78.6	138.9	85.	185.7	91.5	240.9	99.3	304.7
	80.9	142.9	87.5	191.0	93.9	247.9	100.1	314.4
	83.4	147.3	90.2	196.8	96.8	255.4	103.1	324.0
	86.1	152.1	93.1	203.2	99.9	263.6	106.4	334.4
	89.0	157.3	96.3	210.0	103.4	272.7	110.	345.7
	92.3	163.1	99.9	217.4	107.1	282.6	114.2	358.7
	95.9	169.6	103.7	225.9	111.3	293.7	118.6	372.4
	99.9	176.7	108.1	235.9	115.9	306.1	123.5	388.0
	108.0	190.9	119.5	260.5	128.1	338.2	136.3	428.7
.66	138.5	244.7	146.9	319.2	156.8	413.9	167.	524.7
	156.5	276.5	169.1	369.0	185.4	489.6	193.0	606.4
	175.3	309.7	193.0	423.0	202.9	540.0	216.2	679.2
.33	192.3	339.9	207.0	473.6	222.7	588.0	236.6	745.1
.71	207.7	366.9	224.4	489.7	240.5	634.8	256.1	804.4
	222.3	392.9	240.3	524.3	257.4	679.6	274.1	861.1
.22	236.0	417.0	255.0	556.5	273.2	721.3	290.9	914.0
	248.8	439.9	268.8	586.6	288.0	760.4	306.7	963.5
.81	261.3	461.1	282.5	615.8	302.4	798.3	321.9	1011.5
.68	272.7	481.2	294.6	642.8	315.6	833.2	336.1	1055.8
.84	283.9	501.6	306.8	666.4	328.6	866.6	349.9	1099.3
.85	294.5	520.4	318.5	694.9	341.2	904.7	363.3	1143.3
.38	304.9	538.0	329.6	719.1	353.1	932.0	375.9	1181.0
	316.0	558.4	341.4	745.0	365.8	960.6	389.4	1220.5
.64	324.9	574.0	351.0	765.9	376.0	988.7	400.4	1257.8
.11	334.0	590.2	360.9	787.5	386.6	1018.7	411.7	1293.2
.26	343.2	606.1	370.8	809.2	397.4	1048.0	423.0	1329.0
	352.5	622.8	380.8	830.9	407.9	1077.0	434.4	1364.6
.91	369.7	653.3	399.5	871.6	427.9	1130.0	455.7	1431.5
.33	385.9	682.9	417.0	910.0	446.8	1179.5	475.7	1494.4
.92	401.9	710.2	434.2	947.7	465.2	1228.0	495.3	1555.9
.43	417.2	737.2	450.8	983.6	482.9	1275.	514.1	1615.5
.66	431.6	762.7	466.4	1017.6	499.5	1319.6	531.9	1671.1
.5	446.1	788.3	482.0	1051.7	516.3	1363.1	549.8	1727.1
.82	459.9	812.6	496.9	1084.4	532.3	1405.2	566.7	1780.3
.55	472.9	835.6	510.9	1114.9	547.3	1444.9	582.8	1830.9
.68	485.9	858.7	525.0	1145.6	562.4	1484.8	598.8	1880.6
	497.4	881.4	538.9	1175.8	577.3	1523.4	614.6	1930.9
.62	511.0	903.0	552.1	1204.8	591.4	1561.4	628.3	1978.3
.45	523.0	924.2	565 1	1233.0	605.4	1587.6	644.5	2024.9
.48	534.7	944.7	579.0	1263.8	618.1	1633.0	659.1	2070.0
.66	546.5	965.4	590.3	1287.4	632.4	1669.4	675.3	2115.0
	557.7	985.2	602.6	1313.2	645.6	1704.0	487.2	2159.1
.46	568.6	1004.7	614.2	1340.4	658.1	1737.3	700.6	2201.1
.04	579.8	1024.3	626.3	1366.6	670.8	1771.1	714.2	2266.5
.71	590.4	1043.2	637.6	1391.4	683.1	1803.4	727.3	2284.8
.48	600.5	1060.9	648.7	1415.4	694.9	1835.7	739.9	2324.5
.33	611.0	1079.7	660.2	1440.6	707.7	1868.7	753.0	2364.5
.57	659.8	1165.9	712.9	1555.6	763.7	2016.2	813.1	2554.8
	705.7	1246.9	762.5	1663.8	816.8	2155.4	869.6	2732.0
.22	748.4	1322.4	808.6	1764.4	866.7	2286.8	922.2	2897.5
	788.9	1393.4	852.4	1860.1	912.8	2410.5	972.1	3054.1
.18	827.4	1462.0	894.6	1950.9	957.5	2527.9	1019.5	3202.9
.06	864.1	1526.9	933.8	2037.6	1000.1	2640.1	1064.6	3345.1

ing full" means when discharge is maximum; this occurs h of flow is 0.9 × the diameter, approximately.
s *velocity in* feet per minute, and Q the capacity or dis- *cubic feet* per minute, when it is maximum.

Table No. 215

Table showing velocity in and capacity of the large size Pipe Sewers, Conduits, or Culverts of modern Pipe, lengths, as determined by Joseph B. Rider, C.

Grade Required to Produce Velocity.		Diameter of Pipe in inches.					
		27		30		33	
In ft. per 100 ft.	One ft. Fall in.	V	Q	V	Q	V	Q
0.05	**2000.**	**104.1**	**414.**	**112.3**	**551.**	**119.5**	
0.0526	1900.	106.2	422.	114.5	562.	122.5	
0.0555	1800.	109.2	434.	117.8	578.	126.1	
0.0588	1700.	112.4	447.	121.3	595.	129.8	
0.0625	**1600.**	**115.4**	**459.**	**126.3**	**615.**	**133.9**	
0.0666	1500.	119.9	477.	129.4	635.	138.4	
0.0714	1400.	124.1	493.	133.9	657.	143.3	
0.0769	1300.	128.9	513.	139.1	683.	148.8	
0.0833	1200.	137.4	546.	144.8	711.	154.9	
0.1	**1000.**	**147.4**	**586.**	**159.**	**780.**	**170.1**	
0.15	666.66	178.1	708.	192.1	942.	205.4	
0.2	500.	221.7	882.	239.	1173.	255.	
0.25	400.	235.2	935.	253.5	1244.	271.1	
0.3	333.33	258.7	1029.	278.2	1365.	297.3	
0.35	**285.71**	**278.5**	**1107.**	**300.3**	**1474.**	**320.7**	
0.4	250.	297.	1181.	320.2	1571.	342.1	
0.45	222.22	316.4	1258.	341.1	1674.	364.6	
0.5	200.	333.7	1327.	359 6	1765.	385.3	
0.55	181.81	349.7	1390.	377.5	1853.	408.5	
0.6	**166.66**	**365.3**	**1452.**	**393.7**	**1932.**	**419.9**	
0.65	153.84	380.3	1512.	410.2	2013.	438.5	
0.7	142.85	395.2	1571.	425.9	2090.	455.2	
0.75	133.33	409.4	1628.	441.3	2166.	471.6	
0.8	125.	422.5	1680.	456.4	2240.	487.7	
0.85	**117.64**	**435.5**	**1732.**	**470.4**	**2309.**	**502.7**	
0.9	111.11	447.7	1780.	48[illegible].6	2374.	516.9	
0.95	105.26	460.	1829	496.9	2439.	531.	
1.	100.	471.3	1874.	510.1	2503.	545.1	
1.1	90.91	495 7	1971.	535.	2626.	571.8	
1.2	**83.33**	**517.3**	**2057.**	**558.4**	**2741.**	**596.8**	
1.3	76.92	538.9	2143.	581 2	2853.	621.2	
1.4	71.43	550.2	2223.	603.2	2960.	644.6	
1 5	66.66	578.4	2300.	623.9	3062.	666 7	
1.6	62.5	597.8	2377	644.8	3165	689.1	
1.7	**58.82**	**616.4**	**2451.**	**664.7**	**3262.**	**710.3**	
1.8	55.55	633.6	2519.	6[illegible]3.5	3355.	730.5	
1.9	52.63	651.	2588.	702 4	3447.	750 6	
2.	50.	667.8	2655.	720.7	3537.	770.2	
2.1	47 62	684.6	2722.	738.6	3625	789.3	
2.2	**45.45**	**700.8**	**2786.**	**755.9**	**3710**	**807.8**	
2.3	43.48	716.4	2848	772 7	3792.	825.8	
2.4	41.66	732.	2910.	789.5	3875.	843.8	
2.5	40.	747.	2970.	805.1	3951.	860.4	
2.6	38.46	762.	3030.	821.4	4031.	877.9	
2.7	**37.04**	**776.4**	**3087.**	**837.2**	**4109.**	**894.7**	
2.8	35.71	790.8	3144.	852.5	4184.	911.1	
2.9	34.48	804.6	3199.	867.3	4257.	926.9	
3.	33.33	819.	3256.	882.6	4332.	943.2	
3.5	28.57	883.8	3514.	958.8	4706.	1024.7	
4.	**25.**	**945.6**	**3760.**	**1025.**	**5033.**	**1096.**	
4.5	22.22	1002.6	3986.	1087.	5337.	1162.	
5.	20.	1057.	4203.	1146.	5627.	1225.	
5.5	18.18	1100.	4409.	1202.	5901.	1285.	
6.	16.66	1158.	4604.	1256.	6168.	1342.	

V in the above table means the velocity of th feet per minute, and Q the capacity or discha minute, when it is maximum. This occurs w is 0.9 × the diameter, approximately.

FFECT OF ACCELERATION IN VELOCITY OF FLOW DUE TO GRAVITY.

Most formulae assume that resistance of the mateal of the sides of a sewer to flow and other causes .st equals the effect of acceleration due to gravity and at therefore the velocity of flow in the sewer is unirm from top to bottom of a grade, regardless of the ll in feet per hundred.

If this is true, a sled gliding down a steep hill would ot have its velocity increased at all from the time it Et the top.

Look into almost any sewer laid on a moderate grade y one half full at a manhole; go to the next one wn the grade and the depth of flow will often be ss, even though increments of sewage have entered tween. The author has made many experiments to termine the relation existing between size of sewer, pth of flow and grade. The experiments and observans have extended over a period of nearly fourteen ars and he hopes to soon embody them in convenient rm for practical use of the profession. To attempt here discuss the subject would necessitate the use of lculus and is therefore prohibited by the title "Inant Answers." The subject is of sufficient importce, however, to have attention called to it somewhat detail. The following is abstracted from a paper by m as read before the American Water Works Assn. the Phila. meeting in May, 1891, and is given in eference to quotations from other articles on this me subject on account of its describing some of his st experiments.

"Permit me to state the following facts which I ink are not generally recognized:

"First, That for every size of pipe there is a rate of ade, on which, if the pipe is laid, the discharge will a maximum.

"Second, That the smaller the pipe and greater the efficient of roughness, the nearer will this grade approach a vertical line.

"Third, That for a given depth of flow in a pipe (not rking under pressure) there is but one grade on ich said pipe can be laid, in order that depth of flow ll remain constant throughout the length of the conit.

t outlet, on 0.6 per 100 grade, the actual velocity ound to be 3.8 feet per second. Kutter's formula, isual coefficients, gives 3.49 feet per second; re a well constructed 12-inch vitrified conduit g ½ full on a 0.6 per cent. grade, discharged 7.05 feet, or 52.73 gallons per minute more than the ted discharge.

hydraulic mean radius being the same for a inning full, we can say that a 12-inch vitrified t when running full, will discharge 105 gallons nute, or 151,000 gallons per day more than the ted discharge by Kutter's formula.

there is such a discrepancy between calculated ictical discharge for a 12 inch vitrified conduit on de mentioned, how much greater will be the vari- when both grade and size of conduit are increased.

m the above, conclusions can be drawn:

st, That the grade which will insure a uniform y in a well laid 12-inch conduit, when running lf full, is less than 0.6 per 100 feet.

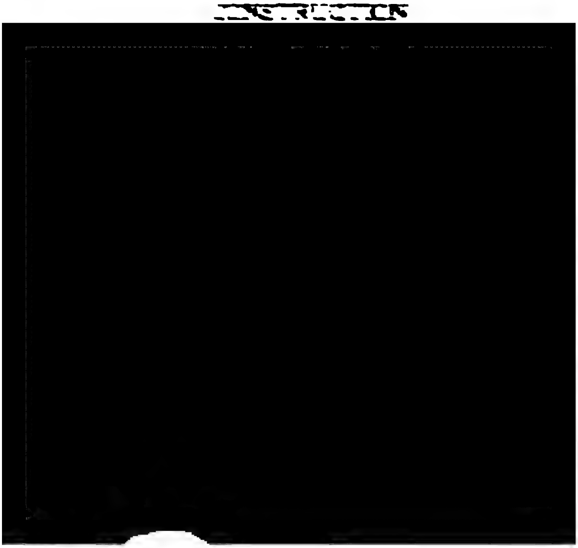
ond, That a 12-inch conduit calculated for dis- ig a certain quantity "Q" must not have admit- o it any increments "Q," if the grade is much an 0.6 per 100 feet.

idea that I wish to bring forward by the pre- remarks is not that it is advisable to lay a con- adually decreasing in area as it reaches the out- ut to take an example: Suppose a conduit to uniform inclination from a point "A," where it s a quantity of liquid "Q," to a certain point own the grade, and that no increments are added distance "A" "B," then there is but one case in the conduit at "B" is necessarily as large as at nd that is, when the acceleration due to gravity is ual to the frictional resistance within the pipe.

w, very few conduits are run on grades that about this equality, and as a consequence the ve- constantly increases from "A" to a certain point which may or may not be beyond the point "B." point "C" the maximum velocity is obtained, and grade and size of conduit remains constant, the y will not change in said conduit from the point the end.

o not mean to say that a conduit should decrease

... AND METHODS OF SEWER CONSTRUCTION



Slip Glazed Pipe

Are made of poor quality of clay, often so poor that it cannot be used for other purposes. After the pipe are made and dried, they are dipped into a solution of argilaceous earth or aluminous clay (mixed to about the consistency of milk) which will melt at a comparatively low temperature, and run over the outside of the pipe before the clay forming the body of the pipe is hard burned.

After dipping, the pipe are set in a close kiln, and a sufficient heat produced to melt this outside covering and cause it to run over the pipe.

This slip glaze is apt to peel off when the pipe are subjected to the action of frost or acid. The body of the pipe not being sufficiently burned, is porous and frequently becomes soft and spongy in the ground.

Strength of Vitrified Pipe.

If properly laid on a good foundation and the earth is well tamped under around and at least one foot over the pipe, average good quality of salt glazed vitrified pipe will carry the following weights of trench earth per lineal foot of sewer.

4 inch	4	tons.
6 inch	3	tons.
8 inch	2	tons.
10 inch	1	ton.
12 inch	0.75	ton.

The amount carried by the larger sizes is too variable for tabulation; for instance, a 24 inch line laid in a careless manner will often crack lengthwise nearly its entire length under a load of 5 to 8 ft. in depth of back-filling while the same line if laid in concrete up to its centre line will resist even as much as the 4 inch above given. Under ordinary conditions if the pipes are well laid, the earth thoroughly tamped, they can be made to resist the weight of back-filling in a twenty foot trench; if care is taken in back filling the earth arches itself, thus relieving the pipe of a considerable portion of the weight. The author has laid all sizes in all depths of trench up to 25 ft. and so far as known never had but one cracked line, this being due to a quick sand foundation.

If the trench is in deep rock it is well to lay stone *alongside of the pipe* line, packing them in thoroughly

ent; thus fill the joint to its face and finally give the al outside taper of about 45 degrees with good cet mortar. Keep water away from outside by carey placing clay or other good material next to it. sure to remove the cement projecting inside of the .

uch a joint after it has set on a rigid line is fully as ng as the pipe itself. It can be used to advantage mergency cases on cast iron water pipe lines. For mains, they are much cheaper than the regular lead t and often preferable. In this connection it may be l to state that in laying iron pipe in locations diffito properly caulk, a sulphur joint can be used; it not need caulking as it does not contract like lead n cooling.

TESTS.

ever test a vitrified pipe line by hydraulic pressure ss it is held rigidly in place; otherwise it will tend ink and twist similar to a hose under pressure.

lways begin at lower end of line to lay pipe. Proper -drain will take care of sub-soil water and allow "dry ng."

RING JOINTS.

Vhere pipe is to work under pressure ring joints are ferable to smooth bell joint but not to the modern it with groove in the bell.

COLOR AND "RING" OF PIPE.

he color of pipe bears little relation to its strength vided a cross section of pipe does not show a conerable variation in the color in distinct concentric gs; this is a sign of poor or inefficient burning or in le cases of improper mixing of material.

'ipes having a distinct metallic ring when hit with iammer, if of proper thickness, with good glaze, d no further inspection. Pipes with a dull ring will resist much pressure and are quite liable to absorb onsiderable amount of water or sewage.

CEMENT PIPE.

ement pipe ought not to be used at all for sewers. der slight pressure when made in the usual manner, n under two or three feet head they will absorb ugh sewage to become "soggy," and even leak. h pipe have no place therefore in a sanitary sewer em.

he above remarks refer only to common pipe, and *o Cement Lined* Water pipe made of good cement *netal by reputable* makers.

Table No. 216

STANDARD VITRIFIED SEWER PIPE PRICE LIST.

(Smaller sizes.)

Adopted by Eastern and Western Manufacturers, January 20th, 1887.

2 inch		**12 inch**	
Per foot	$0 14	Per foot	$0
Bends, Elbows each.	40	Bends, Elbows each.	3
Branches 2 ft l'ng e'h	63	Branches, 2 ft l'ng, e'h	3
....		Traps, each..........	1(
3 inch		**15 inch**	
Per foot	$0 16	Per foot	$
Bends, Elbows, each.	50	Bends, Elbows, each.	
Branches 2 ft l'ng, e'h	72	Branches, 2 ft l'ng, e'h	
Traps, each..........	1 50	....	
4 inch		**18 inch**	
Per foot	$0 20	Per foot	
Bends, Elbows, each.	65	Bends, Elbows, each.	
Branches, 2 ft l'ng, e'h	90	Branches, 2 ft l'ng e'h	
Traps, each..........	2 00	....	
5 inch		**20 inch**	
Per foot	$0 25	Per foot	
Bends, Elbows, each.	85	Bends, Elbows, each.	
Branches, 2 ft l'ng, e'h	1 13	Branches, 2 ft l'ng, e'h	
Traps, each..........	2 50	....	
6 inch		**2[illegible] inch**	
Per foot	$0 30	Per foot	

Table No. 217

ER LINEAL FOOT AND QUANTITY IN MINIMUM CAR LOAD OF 30,000 POUNDS.

IPE	WEIGHT PER FOOT	QUANTITY IN CAR LOAD
	5.0 lbs	6,000 feet
	6.5 "	3,750 "
	10. "	3,000 "
	11. "	2.350 "
	16. "	1,900 "
	25. "	1,250 "
	30. "	1,150 "
	35. "	884 "
	45. "	650 "
	65. "	464 "
	85. "	350 "
	100 "	294 "
	113. "	266 "
	120. "	242 "
	145. "	230 "
	225. "	150 "

.ght of pipe varies from 10 to 20 per cent.

CHARGES FOR SPECIALS.

, charged fifty per cent. more than plain pipe, ured on the long side of the slant but no less iches.

ADDITIONAL BRANCH OR TRAP is charged as ice.

with or without hand-hole, same price, but e than one hand-hole, the additional charge ranch pipe.

STRENGTH PIPE of fifteen inch and above, is ess one-twelfth (1-12) the diameter, is a less than standard pipe, the regular thickness, as d, is entitled "standard thickness."

ERS are pipe with socket on small end, and with socket on larger end, and charged at e price of two feet of pipe of size of larger

ECE TRAP, nine inches in diameter or over, eight times the price of one foot of pipe for

EL OR SPLIT PIPE, which is pipe cut in two or es, lengthwise, each piece charged three-fifths of a whole pipe.

; OR PLUGS for closing pipe, one-third of one e of the size in which it is used.

Deep and Wide Socket Pipe is less discount than Standard Pipe, and has greater depth of socket and more annular space.

Average discount delivered is about 70 per cent.

The following table gives price of vitrified pipe, etc., in Southern California.

Table No. 218

PRICE LIST OF LOS ANGELES SEWER PIPE ASSOCIATION

FOR

SALT GLAZED VITRIFIED SEWER AND WATER PIPE.

Inside Di'm'tr of Pipe	Price per Foot	Branch T's & Y's Each	Curves, Bends, Each	Reducers or Increasers	Hand-hole Traps	P Traps	S Traps	Weight per foot	Feet to Car-load of 10 tons	Area in Inches
3	$0 15	$0 60	$0 50	....	$1 75	$1 25	$1 75	6	3300	7 06
4	20	80	60	$0 60	2 00	1 50	2 00	9	2220	12 56
5	25	1 00	75	75	2 50	2 00	....	12	1660	19 63
6	30	1 20	1 00	90	3 00	2 50	....	18	1110	28 27
8	40	1 60	1 50	1 20	4 00	....	....	25	800	50 26
10	60	2 40	2 10	1 80	6 00	....	....	33	600	78 54
12	75	3 00	2 75	2 25	....	....	....	45	435	113 09
14	1 00	4 00	3 75	3 00	....	....	....	57	350	153 93
15	1 15	4 50	4 25	3 50	....	....	....	61	330	176 71
16	1 25	5 00	4 50	3 75	....	....	....	65	310	201 06
18	1 50	6 00	4 75	....	....	....	....	80	250	254 46
20	1 75	7 00	6 50	....	....	....	....	93	215	314 16
22	2 20	8 50	7 50	....	....	....	....	108	185	380 13
24	2 50	10 00	9 00	....	....	....	....	130	154	452 39
30	3 50	15 00	12 00	....	....	....	....	160	125	706 86

P and S Traps with hand-holes, 25 cents extra. Double strength pipe costs 30 per cent. additional.
Pipe and Branches furnished in two-foot lengths unless by special order.

In comparing prices and discounts, be sure that you are using the same list or are properly comparing different list prices. Certain manufacturers have their own, somewhat at variance with the standard list price.

Blackmer and Post give the following data relative

Size of Pipe.	Width of Trench Required.	Depth of Trench, 6 ft.		Depth of Trench, 8 ft		Depth of Trench, 10 ft.		Depth of Trench, 12 ft.		Depth of Trench, 14 ft.		Depth of Trench, 16 ft.	
		Cost of ditching per running foot.	Cost of laying pipe and cement.	Cost of ditching per running foot.	Cost of laying pipe and cement.	Cost of ditching per running foot.	Cost of laying pipe and cement.	Cost of ditching per running foot.	Cost of laying pipe and cement.	Cost of ditching per running foot.	Cost of laying pipe and cement.	Cost of ditching per running foot.	Cost of laying pipe and cement.
27-inch	3 ft. 2 in.	$0 20	$0 11	$0 26	$0 12	$0 38	$0 13	$0 52	$0 14	$0 65	$0 15	$0 85	$0 16
30-inch	3 ft. 6 in.	0 22	0 14	0 30	0 16	0 43	0 18	0 59	0 21	0 72	0 24	0 92	0 27
33-inch	3 ft. 9 in.	0 25	0 17	0 33	0 19	0 46	0 21	0 63	0 24	0 77	0 28	1 00	0 35
36-inch	4 ft. 2 in.	0 28	0 20	0 36	0 22	0 50	0 25	0 67	0 28	0 82	0 32	1 10	0 36
2 ft. x 3 ft. oval...	3 ft. 8 in.	$0 27	$1 80	$0 35	$1 80	$0 48	$1 85	$0 65	$1 90	$0 80	$1 95	$1 05	$2 00
2½ ft. x 3½ ft. oval...	4 ft. 2 in.	0 33	2 00	0 41	2 00	0 55	2 05	0 73	2 10	0 90	2 15	1 15	2 20
3 ft. round..........	4 ft. 8 in.	0 36	1 80	0 45	1 80	0 60	1 85	0 70	1 90	0 98	1 95	1 25	2 00

The Table is based on the following prices: per hour labor 22.5 cents; pipe layers, 30 cents; brick layers, 55 cents; hod carriers, 30 cents; mortar men, 28 cents. Also on cement at 80 cents per barrel; sand, $2 per cu. ... brick, $6 per 1000. Mortar 1 to 1 for pipe joints and 3 to 1 for brick work.

The author has found it impossible to tabulate bi[illegible] [illegible] or even the bids accepted and for whi[illegible] different works were constructed in such a way as [illegible] value in this work. In fact he is afraid their [illegible] without many notes relative to local conditi[illegible] would tend to make the information valueless [illegible] [illegible] otherwise than confuse.

The following table however may be found of ass[illegible] [illegible] It gives the average cost for certain items un[illegible] various conditions: D means difficult; F, fair; E, [illegible] [illegible] as the terms are generally understood. U[illegible] some of the items is given cost for certain incider[illegible] [illegible] of the item. f means per ft. of sewer; e, e[illegible] [illegible] measure. Iron pipe is based on co[illegible] [illegible] of $20 per net ton.

[illegible] is based on 80 per cent. discount [illegible] [illegible] Table No. 20[illegible]

Table No. 201

[illegible] Certain Items in Sewer Const[illegible]

[illegible] Supervision of Joseph B. Rider, C.[illegible]

	Cost per complete
[illegible] on piles complete	$9.[illegible]
[illegible]	$2.50 e
[illegible]	4.00 e
[illegible]	2.75 e

Table No. 201—Continued

ring and pulling same, light lum-
r .... 0.08 f
ak in bottom, placed, ... 0.02 f
aping water .... 0.05 f
aping .... 0.04 f
nent joints .... 0.025 f
lacing pavements, see table No. 132.

nch vitrified, will cost under similar conditions, not exceed 15 cents less per foot than 20 inch.

nch has averaged in cost for 7.5 ft. trench..$1.05 F
nch has averaged in cost for 7.5 ft. trench.. 0.89 F
nch has averaged in cost for 7.5 ft. trench.. 0.75 F
nch has averaged in cost for 7.5 ft. trench.. 0.76 D
nch has averaged in cost for 7.5 ft. trench.. 0.60 F
nch has averaged in cost for 7.5 ft. trench.. 0.52 E
nch has averaged in cost for 7.5 ft. trench
.................................38 to 50cts. F
inch sub-drains ....$0.12 f
inch .... 0.10 f

ouse connections, 6 inch, 24 cents; 4 inch, 19 cents per foot. Manholes containing (with waste) 2M brick, with 350 lb. cover, $62.00 e. Smaller manholes as low as $38 for average height of 6.5 ft.

ish Tanks, have averaged $80 complete with good syphon. A poor make of flush tank is worse than none at all; a good one is an important factor and much better than depending on flushing with hose.

or cost of sewage pumping wells, see data under en Wells.

BRICK SEWERS.

or capacity see "Discharging Capacity of Sewers.")

The hydraulic mean radius(section of water divided the wetted perimeter, see page 273) should be as ar maximum as possible at all stages of flow. For wer outlets in small municipalities and lateral trunk wers in larger cities egg shape or oval section in-es above condition as near as practical to obtain it.

For main outlets of large cities where depth of flow s not vary between such wide limits, the circular tion *is preferable* as giving the greatest capacity per *yd. of material* used in construction.

[illegible] brick [illegible]

[illegible] ring for [illegible]
[illegible] rings for [illegible]
[illegible] rings for [illegible]
[illegible] thickness and [illegible]
[illegible] diameter. If [illegible]
[illegible] above it, and [illegible]
[illegible] The pressure [illegible]
[illegible] and that the [illegible]
[illegible] prevented from [illegible]
[illegible] earth or [illegible]

[illegible] of T[illegible]

[illegible] line of any [illegible]
[illegible] to the [illegible]
[illegible] with [illegible]
[illegible] verified [illegible]

[illegible] Sewe[illegible]

[illegible] mm. [illegible]
[illegible] mm. [illegible]
[illegible] mm. [illegible]
[illegible] mm. [illegible]
[illegible]
[illegible] and [illegible]
[illegible] good [illegible]

on, returning to established grade on the lower rc not objectionable.

; best to have a manhole on either side and one . cover that can be made "pressure tight" by bar 'edge at lowest point in line under centre or at le of the water course or obstruction, to facilitate ıg if necessary. It is best to make the depressed n of iron pipe somewhat less in cross-section than :wer itself on either side; also to give a slight net grade between the manholes on either side ls of the iron pipe; this will tend to increase the ty and prevent matter in suspension from settling low point. The author has been obliged to con- several inverted siphons and has never experi- any trouble with their clogging. In one case he 'ucted a 24 inch line under a tide water creek; it een in use over 11 years and though centre man- s opened each year, the line has always been found or at least free from accumulation. There is a prediudice against inverted siphons but if prop- lesigned there is no reason why they should clog quickly than an ordinary trap in a house pipe.

SEWAGE DISPOSAL

(For Amount of Sewage see Sewage.)

Disposition Into Streams

bout all there s in life for man is contentment; ut health this is impossible, and no community can althy while drinking bad water." *

trefaction of organic matter is not only objection- from an aesthetic standpoint, but UNHEALTHY. gs popular are often so because cheap, but things › are not always best, or economical though pop- Common decency, reasonable regard for the s of others, and protection of self demands that ge should not be discharged into streams used able to be used for water or ice supply. Every ligent citizen admits that it should not be so dis- ged: many reasons why it should not are given r "Brief Water and Supply Notes."

ithin limits, by proper method, sewage can with nity be discharged into certain bodies of water. ointed out under "Aeration," water does not "pur-

*Quoted from the author's address as given in editorial in nneapolis; Minn., "Tribune." August 22, 1894.

ify itself" by flowing in a stream. To a limited extent, certain organic matter in the water, it must be admitted, combines with the oxygen of the air to form harmless inorganic compounds, but this seldom amounts to sufficient to counteract the effect of introduction of increments of organic matter as the stream flows from town to town or farm to farm.

Many authorities have given the impression that numerous forms of Aquatic Vegetation or Life will absorb all that is objectionable in sewage. It is true that such vegetation will not only live in a water containing sewage, if sufficiently dilute, but that it thrives or feeds upon the dissolved organic matter of the contained sewage. Such life or vegetation will, however, die in concentrated sewage. Again, it is not present in all streams, and even in those in which it is present, it is not active at all seasons of the year, and hence must be eliminated as a factor in stream purification. For the above and other reasons, the micro-organisms (nitrifying bacteria) must be depended upon to perform such net work of purification as does take place outside of sedimentation, except in the case of much hydrogen sulphide or other easily oxidized compounds. Where the health of a community is at stake, nothing but methods reliable at all times should be depended upon. From a business standpoint alone, no municipality ought to rely on "self purification," weeds, grass or other aquatic life to give it pure water to drink.

The nitrifying bacteria must have air, or they will cease work and die. The benefit of aeration is not because of the direct oxidation of organic matter, which takes place in a small degree, but because of the air furnished the nitrifying organisms and permitting them to purify the sewage by bacterial oxidation, as hereinafter explained.

Dilution.

As a general statement, it can be said that from 2 to 5 per cent. of the volume of a stream can be recently discharged sewage and not cause a nuisance apparent to the eye, taste or smell. If the velocity of the current is over two feet per second, the amount can sometimes be doubled, but often when so increased accumulations deposited at stages of stream higher than minimum flow will putrefy prior to

moval by high water. In any case where raw sewage is discharged into a stream or other body of water, it is best to collect by sedimentation, skimming and screens all floating or heavy substances.

TIDE WATER BODIES.

When sewage is discharged into a harbor or other tidal body of water, it will cause a nuisance unless discharged ONLY at outgoing tide at a point or points near enough to the ocean or large arm of it to insure the sewage not being returned by favorable wind or next incoming tide to even above the outlet.

Boston furnishes the best American example of such disposal. The sewage of the city is delivered to and held in large receiving basins on Moon Island, near the mouth of the harbor, and discharged twice daily at ebb tide at the rate of nearly 400,000 gallons per minute. In less than two hours it is so mixed with the sea water that it cannot be distinguished.

Much is yet unknown relative to the bacteria of the sea, but it is presumed that they exist on the dissolved nitrogenous matter.

No harm has been traced to disposal into tide water when discharged at a distance from the beds of shell food.

When discharged over or near oyster or other beds, there is a positive danger from typhoid or other zymotic disease being spread by using them for food. Cases of Typhoid have been directly traced in Italy, Connecticut, and elsewhere to oysters.

CHEMICAL PRECIPITATION OF SEWAGE

Few places that have adopted chemical precipitation are glad of it.

The great majority are looking for some way to utilize their investment in some way in connection with other and more economical methods of disposal.

In practical every-day work, not laboratory experiments, chemical precipitation when carried on under scientfic supervision, will simply separate, in part, the water from the sewage itself; the water plus sewage still in it, flowing off, while sewage is deposited together with the chemicals used at the bottom of tanks or vats in which the operation takes place.

SLUDGE.

The deposit or sludge contains 90 per cent. or more of water and 10 per cent. or less of solid matter. If it is not promptly removed while fresh, putrefaction begins causing a nuisance. Assuming that the sewage contains a removable amount of matter as high as 72 parts per 100,000 or 6,000 lbs. per million gallons of sewage and adding to this the weight of chemicals necessary to precipitate it and we have approximately 4 tons of solid matter per million gallons.

Add to this, assuming it to be 10 per cent. of the total as above given, 9 x 4 or 36 tons of water we have 40 tons as the amount of sludge that must be contended with at average disposal works per million gallons of sewage treated. At Worcester, Mass., it averages this amount.

VALUE OF SLUDGE.

It has no practical value. The nitrogen compounds of the sewage are what give it such theoretical value as it may have as a fertilizer. They will not average over 200 lbs. per million gallons of sewage, therefore about ten million gallons of sewage contains one ton of matter valuable as a fertilizer. As below mentioned, but one-third of the constituent parts of sewage is removed by chemical precipitation; assuming the same average removal of nitrogen compounds, about 30 million gallons of sewage would have to be treated to get the equivalent of a ton of fertilizer worth say $20. It would cost to get it, let alone deliver it as combined with 10 to 20 times its weight of other matter in the sludge 30 x $40 or $1200 or sixty times what it is worth; adding for removal, etc., it can be said that it costs in practice at least a dollar to abstract a cent's worth of "fertilizer" from sewage by chemical precipitation.

* AMOUNT NOT COLLECTED IN THE SLUDGE.

The average results obtained by municipal and other large plants leaves about one-third of the nitrogenous organic matter of the sewage and from 5 to over 20 per cent. of the bacteria in the effluent.

It is obvious that such an effluent, though often clear especially when alum has been used, is dangerous as it may contain disease germs or at any rate food in which they thrive and multiply; see "Typhoid B

best that chemical precipitation has yet been able o is to so clarify a sewage that it can be discharged a nonpotable stream without nuisance. The author had to several times investigate this subject for icipalities and others and he has yet to find either e or abroad a chemical precipitation plant that conitly discharges an effluent such that it could be disrged into a *small* stream and not cause trouble ough subsequent putrefaction.

The danger between the raw sewage and the effluent one of degree only. In emergency cases the method to be commended for by using sufficient chemicals hereinafter pointed out, the bacteria can be killed, as a method for municipalities or institutions to opt, few can or will afford from $5 to more than $30 million gallons of sewage treated for chemicals me or an average total cost, for chemicals, labor, inest, etc., of $40 per million gallons for clarification, t is not sufficient to permit discharge into potable ters. The Worcester, Mass., plant has been operated ler scientific supervision clarifying the sewage from r 90,000 people and even on this large scale, without iting a pound, the cost for chemicals alone is 30 ts per capita per annum, while it is admitted that effluent at times causes a nuisance in the Blackie River. Patented processes adopted at other es have cost, exclusive of interest account, as high $1.50 per capita per annum. Recent experiments at rcester have been made with other methods; septic ks, etc., with a view of reducing the cost for clariition.

Chemicals Used in Sewage Clarification.

Lime is one of the most popular reagents. Calcium cide (Lime) CaO. can be obtained pure by igniting : nitrate or carbonate but that of commerce, being ained by burning limestone or marble, generally conis other ingredients such as alumina, magnesium bonate, etc., in such an amount that the commercial duct contains but 70 to 75 per cent. of its weight in cium oxide; in other words about one-fourth the ght of lime used and paid for increases the amount sludge without assisting materially in the work of ification.

i air lime attracts moisture and carbon dioxide and

alone (without the several other expenses) thirty-three dollars per million gallons of ated. The results show, however, that in cases lime thoroughly mixed with sewage of one ounce per 9 or 10 gallons will kill all of the bacteria or disease-producing hen the amount of lime was reduced to an 1625 lbs. per million gallons of sewage treat- cient to combine with the carbonic acid as ioned, all of the suspended organic matter, . or one-fifth only of the organic matter as by the soluble albuminoid ammonia, 76 f the turbidity and 97 per cent. of the bac- removed at a cost for lime of $8.12 per mil- s with lime at $10 per ton. Reduced to con- t for disinfection, we have the amount used one ounce per 36 or 40 gallons treated.

IRON are used when the sewage is alkaline ination with lime; the lime gives the neces- nity to the sewage.

ing alum, see "Swamp and Colored Waters" t mass is produced (hydrate oxide) and in the bottom it envelops and carries with it e suspended matter.

D COPPERAS.—Copperas (ferrous sulphate) lue when used alone; Lime must be added. g approximately 1200 lbs. of chemicals per lons of sewage or 500 lbs. of copperas and lime, all the suspended matter, 13 per cent. ble albuminoid ammonia, 65 per cent. of the nd 86 per cent. of the bacteria were removed or chemicals of $6.00 approximately per mil- s of sewage treated, assuming copperas to me as lime per ton, or $10.

g the lime, a solution of phenolphthalein in used as a test: Lime is added until a few ne solution introduced into the sewage turns y red.

ng the amount of copperas to 1,000 lbs. and to 800 lbs. per million gallons resulted in a 39 per cent. of the soluble albuminoid am- per cent. of the turbidity and 98 per cent. of a at a cost for chemicals of $9.00 per million

[illegible] —With [illegible] lbs. of ferric oxide used [illegible] per million gallons of sewage, re[illegible] per cent of the soluble albuminoid ammonia, [illegible] of the suspended matter, [illegible] per cent of the [illegible] per million gallons.

[illegible] is explained under "Sewage [illegible]" and under "Filtration." In the experiments when [illegible] was used at the rate of [illegible] lbs. per million gallons of sewage the re[illegible] was [illegible] per cent of the soluble albuminoid ammonia, [illegible] of the suspended matter, 83 per cent of the [illegible] and [illegible] per cent of the bacteria at a cost for chemicals of $[illegible] per million gallons with sulphate of alumina at $[illegible] per ton.

Many other chemicals than those before mentioned have been used with more or less success, but with no less expense, in chemical treatment or disinfection and include carbolic acid, [illegible], charcoal, copper sulphates, chlorine, bromine and many others; when used in chemical precipitation of sewage the effluent must be treated by some method of bacterial oxidation prior to its discharge into a water supply.

DISINFECTION AND STERILIZATION OF SEWAGE

As before mentioned a sufficient quantity of lime wi[illegible]

r of the chemical is lost by sufficient dilution of :wage, and it (the sewage) is changed, if suffic- xygen is present, by the aid of aerobic bacteria narmless compounds, by decomposition without if any odor.

here is not sufficient oxygen present, the anaerobic ia begin the work of change by putrefaction, with disagreeable odor.

infection in transit is a wise precaution; when ef- : it prevents putrefaction within the sewers and zymotic germs. Where discharge is into a stream nposition or putrefaction is postponed until the ge has become thoroughly mixed with the waters e stream, thus permitting the natural changes to nal substances, with less offence from an aesthetic point than possible without such treatment and with impunity from a sanitary standpoint.

here a system of Bacterial oxidation of the sewage t in use, some system of disinfection ought to be so as to minimize danger from zymotic disease g distributed in towns on the stream below.

r a better understanding of the action of bacteria urification of water and sewage, see brief "Water Supply Notes," and the following pages.

nple, yet efficient apparatus is made for disinfect- ewage in transit; its cost, cost to operate, etc., are given here as they can be obtained for the asking the makers; see part 2.

BACTERIAL PURIFICATION OF SEWAGE

is subject embraces two diametrically opposite ods up to a certain point.

the First, we include Broad Irrigation, Intermit- Filtration, Forced or Positive Aeration, and other ods that depend on the presence of much air and BIC BACTERIA (nitrifying organisms) a bacteria so d because they will not live, much less work, ut AIR.

the Second, we include in its many forms, the c TANK; certain aerobic action in bacteria or "Con- Beds, methods that depend on the EXCLUSION of d the presence of ANAEROBIC BACTERIA; a bacteria med because they will not work, much less live in *resence of much* air.

De-composition and Putrefaction are n
ous terms, though to many they mean one
thing.

All have noticed that in the presence of
dead vegetable and animal life will, WITI
SIVE ODOR, decompose or separate into or
tuent mineral and gaseous elements or
through oxidation and combining with mi
form harmless compounds that are or can
by plant life. All this would not occur bu
bacteria.

When the quantity of air is defficient d
and animal life will, with generally very o
putrefy, or it is changed into more com
stable forms, chiefly hydrogen compound
point if the anaerobic bacteria have co
work, in the presence of sufficient air, the
teria begin theirs and have much less w
changing the unstable compounds into h
than if they had commenced work upon
substance in its more stable condition.

Upon the above facts depends the princi
tion of the most up-to-date methods of
fication.

When sufficient has been discharged for the crop, shut off the hydrant and repeat the following day or when needed. Such hydrants are cheap, cost from $1.00 up. A good form of cheap hydrant designed by W. B. Rider, C.E., is in popular use in Redlands and other places in Southern California and elsewhere.

In irrigating land, not extensively used for crops, ditches can be cut on a slight grade approximately in direction of level contour lines and from these cross ditches can be fed; they in turn delivering any surplus to other "main feeders." In cold climates the main ditches should be a foot or so deep to allow room for ice to form a cover. The discharge to main ditches should be regulated by good gates in branches from the main pipe conduit.

In winter as a rule the discharge per acre ought not to be over one-half as much as in summer. It will of course depend on the kind of soil and method of application of the sewage and temperature.

Land Required.

The quantity of land required will depend on its quality. The best land is a free loamy or moderately sandy one covering a porous sub-soil, which in turn is efficiently drained. When it is not, to insure uniform percolation through the soil of the sewage and air and proper discharge of the effluent, underdraining will be

uired will have to be increased as its porosity is creased.

Cost for Preparation of Land.

This will depend on amount of grading necessary, general topography, etc. It has averaged about $250 acre exclusive of cost for land. In Southern California, where little or no grading or ditching is reired in connection with pipe systems, the cost has en simply the cost for installing it, or not over an erage of $50 to $75 per acre. If underdrains are necsary they will add materially to the cost. In any innce it can easily be computed approximately, as near any other engineering work, after proper surveys d study of local conditions.

Cost to Maintain

Will be limited almost entirely to cost for attention properly distributing the sewage. This will vary with e season and area required per inhabitant. Where wns are fortunate enough to be paid for their sewage above mentioned, disposal is not a source of expense it one of income. Again many institutions can best ep their inmates from idleness by using "free labor" the field. Where towns have to pay for labor one an ought to be able to look after 40 acres, or plant r 4,000 people, if he has slight additional help in sere winter or hot summer season or say an annual exnse of $500 for 40 acres.

If land costs $50 per acre or $2,000 for 40 acres, and pense of preparation is another $50 per acre, the instment per capita will be $1.00 On this basis we have the annual expense per capita the following.

terest on the investment, at 4 per cent.	$0.04
ost for labor, assuming one man to look after 40 acres, with additional help occasionally, or $500 per year, we have per capita per year for labor account	0.125
enewals, repairs, etc.	0.015
Total cost per capita per annum	$0.17

If properly conducted, Broad Irrigation will give an luent free of disease germs and all objectionable mater, fit to be discharged into any potable stream at a st approximately equal to but one-half the expense r chemicals ALONE, as used in chemical precipitation

of sewage. While Broad Irrigation is the best possible system for many places, it cannot be adopted as a method of final disposition for others on account of lack of land of sufficient area.

SEWAGE DISPOSAL BY INTERMITTENT FILTRATION

This is simply modified Broad Irrigation, whereby through greater care in the preparation and selection of the soil a greater quantity of sewage can be purified per unit area.

Where it is desired to adopt intermittent filtration and no area of moderately level coarse sand and gravel or other quite porous material is available, a filter bed can be constructed, properly underdrained and connected with receiving and discharge pipes in a manner somewhat similar to a filter bed for water purification.

The filter in no wise acts as a strainer, and any good quality of sand, gravel, cinder or even fine crushed stone or pebbles will answer the purpose. As the coarseness of the material is increased the depth should be also increased in proportion. A depth of from 4 to 6 ft. of material is generally sufficient.

Operation.

As before explained aerobic bacteria in the presence of air are depended upon to perform the work of purification. The organic matter of the sewage is decomposed through or by them and either passes off in the effluent in the form of mineral salts in solution or to the atmosphere in the form of gaseous carbon. The result is that where sand from streets, or other inorganic matter is not carried by the sewage, that the body of the filter bed or other prepared area will after years of use be free from foreign matter. Where there is much matter in suspension in the sewage (visible to the human eye) it tends to clog the top portion of the bed or other area; it can be "turned under" by ploughing or otherwise after which it will be consumed as above mentioned or it can be raked off the bed after it has dried. A new filter bed or other area will not do one-fourth the work, when measured by the degree of purification effected, that it will after the aerobic bacteria have multiplied within the bed. It is best therefore not to have a bed out of use for many days at a time

and it is better to operate them in winter than to let them remain idle; otherwise, having no food upon which they can thrive, the aerobic bacteria cannot live, and the filter must be again adjusted to working conditions.

METHOD OF APPLICATION.

Sewage should be applied intermittently to the bed at a rate slow enough to insure proper association of organic matter, air and aerobic bacteria until the bed is well covered; the sewage should then be diverted to another bed. and the sewage in the first bed allowed to slowly drain to the underdrains and thence to the outlet; after air has had the chance to circulate in bed No. 1 for at least a few hours, a day or so is better, it can again be used. Likewise with No. 2 or any other number of beds.

OPERATION IN WINTER.

In winter when climate is not too severe the beds can be operated but generally at a slower rate in gallons per acre of bed per day on account of reduced activity of the aerobic bacteria.

When frost penetrates to a depth of a foot or more, it is best to arrange the surface of the beds with parallel trenches a few feet apart that can be covered by planking; the sewage will penetrate from the trenches to all parts of the bed up to the frost line, and often "melt" much of the frozen earth.

QUANTITY PURIFIED.

The quantity purified per acre per day will vary with the material, efficiency of under-draining, quality of the sewage, etc.

An average well prepared bed or natural area, well under-drained will take care of from less than 60,000 to more than 100,000 gallons per day, giving an effluent practically free of bacteria and with 95 to 99 per cent. of the organic matter of the sewage removed, while the discharge or effluent will be colorless, clear and free of sediment.

Often the amount per acre per day can be as high as *200,000 gallons* and the effluent sufficiently pure to permit *of its* discharge into streams without danger of *subsequent putre*faction or decomposition.

Cost to Construct

Will depend so much on local conditions that no tabulated data would be of value. Where there is sufficient area of land of suitable soil and expense of preparation is limited to cost for under-drains, conduits, and connections and grading, the cost per acre of bed will not in many instances exceed $2,000.

If the entire bed has to be made from "carted" material, 1650 cu. yds. one foot deep or 6500 cu. yds. for a filter bed four feet deep, per acre, must be paid for. The cost is simply a matter that must be decided locally. In a general way it can be said that the cost for the delivery of an effluent pure enough to drink with impunity can be obtained by Intermittent Filtration for one-half the cost (every item of expense considered) that would have to be expended for chemical precipitation that at best could not deliver an effluent fit to be compared with it. Intermittent filtration delivers an effluent when plant is properly operated that can justly be called WATER while a chemical precipitation plant cannot deliver better than a CLARIFIED SEWAGE.

SEWAGE DISPOSAL BY BACTERIAL OXIDATION AS ASSISTED BY FORCED OR POSITIVE AERATION.

In principle the intention is to supply the aerobic bacteria (nitrifying organisms) with more oxygen than is delivered to them under normal conditions existing in a Filter bed. They do not care how they get the air, whether it is from an air pump, blower, by direct current or circulation of the atmosphere; the more air delivered to them (within limits) the more active they will be; the more work performed by them and the more aerobic bacteria there will be to perform the work in a unit area or more correctly unit volume of the filter.

In 1894, Col. Geo. E. Waring, Jr., constructed an experimental plant at Providence, R. I., involved FORCED Aeration; subsequently others have done the same and patents have been granted for certain details.

Circular information, mentioning patents, has so frightened many, that they have refrained from using *air* (which ought to be free) in purification.

In answer to frequent communications relative to this matter, the author can simply state, as given

page 347, paragraph 2; and refer to Fig. 43, page 349 which shows a filtering medium using forced aeration designed and constructed under his supervision in 1892. He certainly will see to it that the several plants constructed by him using forced aeration since 1889 are not stopped by threatening letters, etc., relative to patents. In 1889 he began his work and experiments in this direction with sewage.

In connection with his upward filtration experiments, they have been almost continuously carried on, along lines that depended on forced aeration of the filtering medium and separation by centrifugal force of sand and other heavy matter.

His results have in a measure been a disappointment in that he has not yet been able to purify sewage by forced aeration and filtration for as small an expense as by intermittent filtration, where every item of expense is considered. He has therefore not advised its adoption, though the degree of purification effected is fully equal to that obtained by Broad Irrigation, Intermittent Filtration or any other nearly perfect method depending on bacterial oxidation.

Where available area is limited to sq. rods instead of acres, it is the only method that can be adopted that will deliver an effluent fit to drink. In cases where suitable material for intermittent Filtration Beds is expensive, Forced Aeration may be less costly, but in any case it is cheaper than Chemical precipitation; requires little, if any, greater room and above all is efficient beyond comparison.

SEPTIC TANKS

A septic tank, as its name implies, is one which tends to produce putrefaction. As some one has expressed it "It is simply a well regulated cesspool."

As mentioned at the beginning of this subject of Bacterial Purification of sewage, in order that putrefaction can occur, air or oxygen must either be absent, or present in such small amount that aerobic bacteria (nitrifying organisms) are not able to live and work. When this is the case anaerobic bacteria will be present and *putrefactive changes* will take place; the solid or suspended organic matter in the sewage will be changed

matter in solution or in other words changed to liquid form. For this reason the anaerobic bacteria are often called liquefying bacteria and the change from a solid to liquid state, Hydrolysis.

It was some years ago thought necessary to have the tank "air tight" in order that putrefactive changes could occur; why so, it is hard to tell, for a look into any ordinary cesspool would have convinced the most obstinate that such was not the case.

More recent practice has demonstrated that such changes will take place in almost any tank, if not too much exposed to the action of the wind and the ratio of its area in sq. ft. to its depth in feet is not much greater than 150 to 1. In such a tank a flocculent mass an inch or more in thickness often accumulates on the surface of the liquid. When the sewage is not much heated by the sun while in the tank and remains practically quiet, there is little tendency for the atmosphere to mix with the sewage under the coating.

With the matter in suspension in the original sewage changed to liquid state or into solution, it is best to remove the effluent prior to further and more complex changes, that would retard rather than hasten final purification, by aerobic bacteria.

The object of a SEPTIC TANK therefore is simply to change the organic matter in suspension to a liquid state in order that it can be more rapidly de-composed by aerobic bacteria. Proper operation of a septic tank reduces the amount of suspended matter in the sewage fully 40 per cent.; it does not remove it, but changes it to a liquid form; hence the effluent from a septic tank is more impure than the original liquid portion of the sewage; but it being more free of suspended matter, it tends to clog the surface of any filtering medium through which it may be subsequently passed much less rapidly than raw sewage. This advantage is a material one and when added to that of having the effluent in condition for immediate attack by the aerobic bacteria, it results in practice in being able to purify the effluent at a much more rapid rate per unit area of filtering medium, by any one of the methods depending on aerobic bacteria.

In practice, it is best to discharge the sewage into the tank at a point under the surface thus preventing

›duction; also it is best to take the discharge from the centre so as to not break the top or flocculent ;eal by whirlpool or to carry with it such deposit as · be on the bottom. This bottom deposit, if care is :n to separate sand, grit, etc., before entrance of sewage will not amount to much. An arrangement septic tanks in duplicate is best; but one can be used, :he constant or nearly constant velocity of entrance l discharge is not enough to appreciably form a cur-t, great enough to interfere with anaerobic action.

ʌAGE DISPOSAL BY BACTERIAL OR "CONTACT" BEDS.

›acterial Beds are simply filters made of coarse ma-al such as broken stone, clinkers, coke, etc. The th of medium used varies from 3 to 15 ft. but in :tice 3 to 6 ft. is found ample and best, everything sidered. Such Beds are the outcome of English ls in contending with the problem of sewage puri-tion. Municipalities that could afford the expense chemical precipitation were confronted with subse-nt putrefactive changes in the effluent after its dis-rge into streams; others that desired to have the ·e perfect method of intermittent filtration could not pt it because of lack of room in some cases and : of suitable material in others for the beds. To J. Bibdin, the well known chemist, is entitled most, ıot all, the credit for this method of purification. ton, England, was the first place to use such beds.

OPERATION.

he sewage should preferably have septic treatment ›re its discharge into the beds, for reasons before ›tioned.

he sewage is allowed to "run in" until the bed is l covered and allowed to remain for from two to : hours, depending on the amount of work perform-›y the anaerobic bacteria in the septic tank; if work ;eptic tank is well done, further hydrolysis within bed is unnecessary, and the time can be shortened. he Bed is then drained and allowed to thoroughly ıte, when it is again ready for use. When the sew-used in the beds is as above stated, thoroughly ted in the septic tank, the bed can be filled and ›tied three to four times per day, six days per week,

[illegible] the filter is above the
[illegible] filter from the first bed is p[illegible]
[illegible] small bed of somewhat finer
[illegible] improvement of the orga[illegible]
[illegible] filters will be removed during
[illegible] as shown
[illegible] moving the sewage thr[illegible]
[illegible] bed over [illegible]
[illegible]

[illegible] Filters [illegible] where th[illegible]
[illegible]

[illegible] would be rapidly filled an[illegible]
[illegible] first bed should b[illegible]
[illegible] be reversed by
[illegible]

[illegible] Bacterial

[illegible] used in
[illegible]
[illegible] make No.
[illegible]
[illegible]
[illegible] the mould
[illegible]

s the average rate of flow per sq. ft. of area pro-
l in a SINGLE CONTACT PLANT to 33.6 U. S. gallons sq. ft. per day or to 1,463,616 gallons or say ap-imately 1.4 millions U. S. gallons per acre per day. other "contacts" (passing through other beds in ion) we have the following table.

Table No. 222

A RELATIVE TO CAPACITY AND EFFICIENCY OF BACTERIAL OR CONTACT BEDS.

of acts or Beds.	Net Capacity in U. S. Gallons per day Per sq. ft. of Beds Constructed.	Per acre of Beds Constructed.	Removal of Organic matter in per cent.
[	33.6	1,400,000	50.
2	16.8	700,000	75.
3	8.4	350,000	87.5
1	4.2	175,000	93.75
5	2.1	87,500	96.875

ithout extending the above table it shows the fol-
ng facts.

. That a single bacterial bed will for a merely nal sum, (the interest on the investment plus cost light attention) clarify a sewage (septic sewage) as ency as is possible at great expense by chemical pitation.

d. That the rate of flow when so clarifying can ach that used in purification of drinking water and when averaged among active and idle beds the is not far from one-half the rate used in water ication.

l. That as the number of contacts or times the ef-t is passed through separate beds is increased, the of plant and degree of purification are also in-ed.

. That when the number of contacts is sufficient sure a degree of purification equal tc that obtain-by intermittent filtration, the area of beds must be ast equal to the area used in Intermittent filtra-

. That when the area is thus increased, the capi-d cost is much greater than that of an intermittent tion plant, while the efficiency of purification "day d day out" cannot be so confidently relied on as *intermittent filtration* is used.

plant is limited.

8th. That when the degree of purity ‹
increased to a DRINKING WATER STANDARD
available for purification plant is small, the
not be used.

9th. That when area available for plant
the degree of purity of effluent fixed at
WATER STANDARD, exclusive of distillation
Positive Aeration to supply the requisite o:
aerobic bacteria is the only method that
cessfully adopted. That under any condi
maximum degree of purification for minim
final step in sewage purification should de
work of aerobic bacteria (nitrifying organ
volved in some adaptable method of pu
Biological or Bacterial oxidation.

AIR COMPRESSORS

For weight of free air see page 243.

For change in weight per unit volume wl
perature is increased, see "Heating Rooms
ings."

From Mariottes law we have, "The de
and the same quantity of air is proportiona

e efficiency of air compressors is greatest at sea and decreases about 1.5 per cent. for each 500 ft. evation or more accurately as given below.

Table No. 223

CIENCY OF AIR COMPRESSORS AT VARIOUS ELEVATIONS ABOVE SEA LEVEL.

ation in ft.	Barometer in Inches. (mercury)	Efficiency of Compressor In Per Cent.
level	30.00	100
500	29.42	98.4
1000	28.85	96.9
1500	28.34	95.5
2000	27.78	94.
3000	26.74	91.
4000	25.7	88.1
5000	24.73	85.9
6000	23.83	82.8
7000	22.93	80.2
8000	22.04	77.5
9000	21.22	75.1
10000	20.43	72.7

iring compression air rises above the normal. During xpansion it drops below the normal the amount it above in compression.

Table No. 224

IDS COMPRESSION AND CORRESPONDING TEMPERATURE FROM INITIAL TEMPERATURE OF

deg. Fahr. Temperature.	Pounds Compression Advancing by One Atmosphere.	90 deg. Fahr. Final Temperature.
60	0	90
177	15	212
255	30	294
319	45	362
369	60	417
416	75	465
455	90	507
490	105	545
524	120	580

[redacted]

pressed to 60 lbs. pressure	pressed to 60 lbs. pressure	pressed to 60 lbs. pressure

Table No. 226

(The Gardner Governor Co.)

Air Compressors.

Single, belt driven, Class A.

Code Word	Air Cylinder		Revolutions per Minute	Piston Speed per Minute	Capacity Cubic Feet Free Air		Air Pressure	Horse Power	Pipe Openings			Diameter of Shaft	Wheels		Floor Space			Approximate Weights	
	Diameter	Stroke			Per Minute	Per Revolution			Suction	Discharge	Jacket		Diameter Inches	Width Inches	Length Inches	Width Inches	Height above Foundation Inches	Wheels	Complete Compressor
Mackerel	6	6	150	150	29	19	100	6	2	[illegible]	[illegible]	2¼	30	4¾	60	22	24	500	1150
Madeira	8	8	150	200	67	45	100	14	[illegible]	[illegible]	[illegible]	2¾	40	6¼	76	30	32	600	2000
Maggot	10	10	150	250	135	90	100	28	[illegible]	[illegible]	[illegible]	3¼	48	6¾	90	33	40	1000	3000

Single, steam driven, Class B.

Code Word	Size of Cylinders			Revolutions per Minute	Capacity Cubic Feet Free Air		Air Pressure	Horse Power	Pipe Openings					Diameter of Shaft	Wheels		Floor Space			Approximate Weights	
	Steam	Air	Stroke		Per Minute	Per Revolution			Steam	Exhaust	Air Inlet	Air Outlet	Jacket		Diameter	Width	Length Inches	Width Inches	Height Inches	Wheels Complete	Compressor

Table No. 229

ɛNGTH OF MAIN AND HIP RAFTERS, TRUSSES, ETC.

(W. B. Rider, C.E.)

MAIN RAFTERS.

in inches per ɔot of base.	Corresponding length of Main Rafter in inches.
1	12.0156
2	12.168
3	12.384
4	12.696
5	13.00
6	13.392
7	13.896
8	14.491
9	15.00
10	15.62
11	16.278
12	16.9705
15	19.209
18	21.656
21	24.186
24	26.832
27	29.546
30	33.215
33	35.114
36	38.00
42	43.68
45	46.572
48	49.473
RESPONDING DATA FOR HIP OR VALLEY RAFTERS.	
1	16.992
2	17.081
3	17.221
4	17.429
5	17.648
6	17.99
7	18.442
8	18.775
9	19.046
10	19.681
11	20.218
12	20.778

ıe hip or valley rafter lengths given are for each of base of the main rafter. The main rafter ths are for each foot of base of or covered by th *rafter.* The table will also be found convenie *ss work.* embankments, etc.

INDEX

TO

PART ONE

OF

RIDER'S

LITTLE ENGINEER

e:—

The numbers **without** the letter T immediately pre-
ng, refer to page numbers. Those **with** T immedi-
y preceding refer to Table numbers. Such minor
ds as "and" "on," "in," "between," etc., are at times
tted for typographical reasons. Such common abrevi-
ms as diam. for diameter, rad. for radius, cir. for circle,
, are used. Also at certain places where their use
not be well misunderstood, W. for water, W. W. for
ter works, S for sewers, SD. for sewage disposal, F &
for filtration and aeration, F. for filter, F–B for filter
ls, P. for pressure, Vel. for velocity and others are
d.

A

e-foot, value of, 24.
mt. in inches rainfall, 191.
ation, see also F. & A.
ith upward filtration, 58-361.
rced, sewage purifcation, 8.
der filter beds, 1st. use, 7.
Nantucket, Mass., 347.
tents, 362.
ecautions in design, 357.
ect on sewage, 433.
ter supplies, 356.
ect on algae, growths, 356.
ect on disease germs, 356.
f purification, streams, 6.
es, 338.
r
ntents of, space occupied
, volume of, weight of,
c., 243.
free, not patentable, 448.
ildings, heating of, 400.
ompressed, table temp's. 224.
fect, excess, in combustion, 44.
ure, *effect on life*, 410.
fect, nitrifying bacteria, 34.
ect, potable water, 356.
ansion when heated, 400.
direction flow, water, 359.
sand agitation, 1st use, 347.
heat to raise temp. of, 400, T207.
in pump chambers, 313.
Mariotte's law, action of, 454.
amt. required to burn fuel, 245.
amt. required to support combustion, T147, pages 244, 245.
amt. required by persons, horses, etc., for breathing, in comfort, 402.
chambers, suction pipes, 313.
compressors, 454-457.
leaks, in boiler settings, 297.
pumps, 308. cost to run, 310.
Algae growths, see also vegetable.
in artesian waters, 321.
do not thrive in dark, covered reservoirs, food supply, etc., 321.
in stored waters, 340.
effect aeration on, 356.
Algebraical signs, 5, 6.
Alum, see sulphate alumina.
action of, filtration, 357.
historical, W purification, 347.
use of by John Rider in 1846, 361.
use of in S purification, 3[illegible]
440.

Amphere, value of, 243.
Analysis of
 coals, T148.
 faeces and urine, T211.
 sewage, foreign cities, how expressed, 409.
 sewage of Lawrence, Mass., 407.
 soil, reservoir bottoms, 341.
 water, conversion table, T195.
 water before and after filtration at Nantucket, Mass., 348, 349.
 water, purified, Norfolk, Va., 358.
 angular or circular measure, T19.
Animal growths in water, 343.
 at Nantucket, 348-351.
 at Bethel, Ct., 350-353.
 effect aeration on, 356.
Apalachicola, Fla., fire, 362.
Apothecaries measure, T37.
Apothecaries weights, T3.
Apparatus, disinfection, 441.
Arc, circle, length of, T49.
Area, circles, see circles.
Area, circular, equivalent irregular, and equivalent circular of irregular, 68.
Area
 cast iron pipes, T120-131.
Arid lands, irrigation of, 320.
Arithmetical complement, 49.
Arithmetical signs 5, 6.
Artesian wells, see also wells.
 nitrates in, algae in, 321.
 supply to, etc., 322.
Ash, in various coals, T148.
Asphalt, weight of, T108.
 pavements, 174-176.
 block, how made, 174.
 joint, pipe and masonry, 391.
Atmosphere, mean pressure of, 300.
 atmosphere, mercury and water columns sustained by, 300.
 atmosphere, pressure of, 241.
Avoirdupois weight, 11-13.

B

Back-filling, rock, sewer trench, 423.
Bacteria
 aerobic, work of, 441-442.
 intermittent filtration, 446-7.
 food necessary, 447.
 killed by lime, 439.
 killed by lime & coperas, 439.
 killed by ferric sulphate, 440.
 killed by aluminum, 440.
 in effluent, chemical precipitation, 436-7.
 nitrifying, work of, 434.
 removed by, filtration, 447.
 sea water, 435.
 bacterial-beds, 451.
 bacterial oxidation, principles of, 441, 448.
 bacterial purification 441-454.
Barometer, mercury.
 elev. corresponding to vacuum, temp. etc., air T190.
 inches water, T186.
 effect, air volume, 2
 effect on weight, 10-11
Barrel
 cu. ft., in., yds., in, 2
 U. S. gallons in, 26.
 dry measure, flour, T
Bartow, Fla., roads in,
Beams, floor, streng T228.
Beds, "contact," 451.
Belgian block, pavement
 specifications, abstrac
 cost of, T112.
 So. Norwalk, Ct., pav 176.
Bell-holes, pipe lines, 131.
Bethel, Ct., filter plant 351-2.
 water supply, vegetable ter in effect, hat in 344.
Bidders, macadam road structions to, 169.
Blackmer & Post, sewe T219.
Boards, under sewers, 424.
Boats, fire, see fire b
Boilers, steam, 293.
 blowing off, 298.
 capacity of, how me 295, 282, statements to, 240.
 economy of, how exp 282.
 evaporation of, 299.
 evaporating tests 29
 grate surface of, 29
 heating surface, 295 T175.
 horse power of, 283 287.
 horse power, steam b 406.
 number, proper fire tion, 364.
 pressure carried by 295.
 safety of, 294.
 safe pressure, to find,
 safe pressure "battery
 leaks, steam, effect, 2
 working strain, to fin
 plates, thickness of, 2
 tensile strength, shel
 setting, leaks air in,
 feed-pump for, pipe 299.
 feed water for, mea 299.
 feed water, ana T180, T181.
 feed water, sion, 298.

[illegible], 296.
[illegible]
[illegible] for size of, 297.
[illegible] fuel [illegible] meth-
[illegible] various kinds.

[illegible] surface of,

[illegible], etc. of,

[illegible] by, amt., 299,
[illegible]
[illegible] of, 316.
[illegible] troubles, remedies.

[illegible] in, 345.
[illegible] C.E. [illegible]
[illegible] for
[illegible]
[illegible] for
[illegible]
[illegible] of,

[illegible] threads of, 249.
[illegible] for [illegible]
[illegible] required, 102
[illegible] of, T108
[illegible], rupture of, 177.
[illegible] sewer [illegible]

[illegible], 177-118.
[illegible] sewer [illegible]
[illegible], thickness, 332
[illegible] walls, thickness, 331
[illegible] walls, see retaining

[illegible] damage by electricity
[illegible]
[illegible] 102, lumber for,
[illegible]
[illegible], N. Y.
[illegible] pavements in, 179.
[illegible] wells for, 332.
[illegible] Walter, Mayor, let-
[illegible]
[illegible], disinfection; 440.
[illegible] Chas., C.E., expert-
[illegible] T135.
[illegible], standpipes for, 369.
[illegible], 400-406.
[illegible] rates on, 366
[illegible] H., C.E., book of,

[illegible] cu. ft., cu. yds., in,

[illegible], struck, etc., 26, 27

C

[illegible] electric, damage to,

[illegible]
[illegible], 176
[illegible] inch, 24; reduction
[illegible] T160; discharge in,
[illegible] T161.
[illegible] value of, 241, T145.
[illegible] discharge of, 273.
[illegible] ments, 378.
[illegible] fire streams, 360.

[illegible] pipes, see pipes, etc.

Carats, weight of, 10
Carbon
amt., various coals, T148.
combustion data, T147, etc.
[illegible], prevent purification,
[illegible]
Carbolic acid, disinfection,
[illegible]
Carbonic oxide, combustion,
[illegible]
[illegible], sewer pipe, T237
[illegible], water pipe, T130-131,
[illegible]
[illegible] in [illegible], three units, T188
[illegible]
[illegible], [illegible]
for bridges, 103.
special, water works, T135.
[illegible] pipe, T134
[illegible] iron, [illegible] T144.
[illegible]
[illegible] plastering walls,
[illegible]
[illegible] under pressure, 380,
[illegible] in concrete, 122
[illegible], see [illegible]
[illegible] 180
[illegible], effect lightning, 366.
[illegible] for streets, 121,
[illegible], paving, 175
[illegible], see [illegible]
[illegible]
[illegible] gravity, irregular sol-
[illegible]
[illegible] gravity, wedges, 70
[illegible] force, [illegible]
[illegible] by [illegible] of,
[illegible]
Centrifugal pumps, 290-291.
excavation, amt. by, 290,
330
excavation by, cost, 330.
[illegible]
331.
Chain, surveyors, 15, T17, T18.
Chaldron, Canada, 24
Chambers, intake, see intakes.
Channels, natural, flow in, 272.
Channels, made, flow in, 272,
273.
Charcoal, refuse, for roads,
179
Charcoal, weight of, T108
Chemical examination
conversion table, T195.
Nantucket filtered water,
348.
Chemical precipitation, sew-
age, 435-41.
Chemicals used, sewage dispo-
sal, 437-41
Chert, weight of, T108
roads, 179.
Chimneys & stacks, 291
circular, size, thickness,
wind strain, 293; H. P. of,
T171
coal, draft, etc., 291.
draft, measure of, T186.
flues long, effect of, 293.
gases, composition of, 292;
effect downward flow of,
293; pyrometer tests, 293.

[illegible]

Chord, value of, 126
California, [illegible] 24
[illegible] see curves
[illegible]
[illegible] 250
[illegible] road [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 179
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
areas of diam. in eighths, etc., 1-64 to 100 ft., 154-[illegible]
Circular area [illegible] irregular, 88
C[illegible] or angular measure, [illegible]
Circular annulus, area, etc., 72
Circumference, circles, 56, etc.
Circulation, waters, reservoirs,
Coins, nations, [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
Condensation
in cylinder, [illegible]
[illegible]
Condensers, [illegible]
ter, 308; surf[illegible]
tion of, 310, [illegible]
injection wa[illegible]
and, rule, 3[illegible]
ally water [illegible]
346.
Conduits, com[illegible]
discharge of [illegible]
table, T140 [illegible]

... and costs,

... 344
... ...

... by, T102.
... ..., ... of.

... fig. 21,
... discharge of.

... methods,
... construction, etc., 331.
... surface, 28; con-
... diagonal, etc., 75.
... tables of, 0.1
T48-T61.
... rule examples, 37;
... examples, 38; of
... 0.1 to 1000, T46.

... in acre, T31-34.
... 10 equivalents of.

... 82 equivalents of.

... 28 equivalents of.

... discharge pipes to
...

... ... from ...
... T181, T213.
... ..., etc., ...
... ..., ...
... T212.
... ..., etc., 1,
... gallons, 291.
... in, ...
... T100.

... ... 162.
... of, T215, ...
... ..., paving for, 161;
... T219; cost to lay,
... ..., T220.
... ... U. S. equiva-
... T44; ... ...

... ..., 272.
128-147; index table,
... case of, 128;
... ... and defin.,
... central angle, 129.
... curves.
... 129.
... ... of, T106.
... subtended by, T102.
... sin. angle, T102.
... length of, T103.
... length of, T103.
... ang. 129; sin. of,
... formulae for, T103;
... T104.
... dist., 129.
... for, T103.
... and distance, T103.
... for 1 ft., 133.
... on curves, 137.
... railways, 138.
... railways, 138.
... curve, T102.
... ordinates.
... T103.
... 7

... of, T105, T105A.
use, ordinate, formulae,
..., tables of, T105.
practical problems, in loca-
tion without transit, fig. 30
31, 32.
without chain, fig. 26.
re-locate through point, fig.
27.
connect two parallel lines by
reverse curve, fig. 28; for
others see 141-147.
Radius, length of, T102.
radius 1 deg. curve, T102.
radius any curve, T103.
radii, tables of, T104.
radius track quickly, 134.
tangential ang., 129, ..., ...
tangent dist., fig. ..., 129;
T103, tables of, T104.
tangent dist. fig. 22, 130,
formulae for, T102, T103;
length for 1 deg. curve,
T107.
tangent deflection, 130.
tangent, length to hold, fig.
21.
"Cut-off," engines, ...
effect on ..., ..., 302.
best point of, 302.
mean pressures for different
points of, T178.
Cuts and fills, 77; shrinkage
160.
Cycle paths, 162.
Cycloid, area of, 55.
Cylinder, area of, 57.
Cylinder or prism, contents
73.
frustum of, contents of, 75.
pumps, see pumps.
engines, diam. for given h.p.
308.

D

Dams, 378.
built by W. R. & J. R. Rider,
384.
core walls; construction, di-
mensions, effect, frost on,
foundations for, 383.
curved masonry; dimensions
comparisons, cut Croton
dam, etc., 394-5.
dangerous, monograph on,
386.
down stream banks of, 379.
embankments of, 378-383;
see also embankments.
flow over, 271.
foundations
subsoil removal, sealing
over, asphalt covering,
378; porous soil, quick-
sand, forcing cement into,
379.
frost line, effects, danger,
cautions, 385, 386.
ice thrust on, 386, 387.
intakes, see intakes.

INDEX.

Diagonal [illegible] 55
Discharge [illegible] water, 342.
Discharge
[illegible] T225.
[illegible] 273
[illegible] T149.
[illegible] 384.

E

[illegible] 275.
Electrolysis, [illegible]
pipe fig. [illegible]
Elevations, [illegible]
Elevation [illegible]
238
Embankments, [illegible]
contents of, 77

278, 302.
horse power
icator, 303.
chase of, 305-
:-off," 304.
for given h.
. stroke, lap,
iet, 305.
." on piston,
pumping en-
of, 315-317,
example, 303.
›ld, 337.
. J., roads of,
t. of, 318.
319; grass,
d. 318; reser-
18; river bot-
96.
245.
coals, T148.
ı, at 212 deg.,
: water, 340.
;ical, Nantuc-
.
:ugal pumps,
utio:s, 390.
149.
)-131, T139.
and amt. of,
. cost, etc.,
T211.
heating, 406.
heat, effect
ry joint, 391.
., ratios, 306,
:hor's.
avity, 419-22.
li.ıes, 194.
pipe lines,
'or in rock ex-
ewage, T211.
-s, 241-2.
C.E., table,

Feed water, 298.
amt. for boilers, T169, 282.
amt. for pumping engines, T179.
saving by heating, T170.
Ferric sulphate, 440.
Ferrous sulphate (copperas), 439.
Fertilizer, from sewage, amt. of. cost to produce, value, 436.
Fencing, roads, 164.
Filters, 347-362.
Bethel, 351-353.
household, stone, rate flow, 324.
Nantucket, plan of, 349.
Filter-beds
construction, materials in, 353-5.
construction details, 353-4.
cost of. ordinary conditions, various conditions, places, 355.
sand from hard pan for, 355.
rates flow, all classes water, 355.
for sewage, 446-454.
Filtration & aeration, 347-362,
Bethel. Ct., 351-353, letter from W. commissioners. giving cost. operate, etc., 351.
Lawrence, 351.
Nantucket, Mass., plan, analyses, costs. etc., 348-351.
Phila., author's report at, 254. 357.
mechanical, 357-358.
cost and results at Norfolk, Va., 358.
historical. 347.
pressure type. other types, 357.
agitation bed by air, 357.
upward, 358, 361.
author's experiments, 359, 360.
Fire at
Apalachicola, Fla. 362.
Jacksonville. Fla., 362.
Fires, temp. buring material, 362; corresponding color, T198.
Fireman, water works from his standpoint, 362-374.
Fire boats, 370.
size mains supplied, data, relative to mains, hydrants, relief valves, signals, freezing, salt water, etc., 370-1.
Fire brick, fusing point. T198.
Fire dep'ts, popular, 334.
horses, street sprinkling, 189.
Fire protection
efficiency, various systems, 363.
distributions for, 365.
proper size mains, 364.
effect size mains on insurance rate, 365.

Fire streams
effect temp. fire on, 362.
effect on stand pipe pressure, 364.
effect siamesing. 369.
discharge of, T201.
best pressure, 371.
how to distribute, 362.
effect size nozzles, 372.
effect too great pressure, T200.
height, average of, 372.
loss head in mains by, 372.
quantity water needed, 372.
number, various places, 373.
"stripping," 372.
Fire steamers, 369.
capacity of, 369, 370.
cisterns for, 370.
streams delivered by, 370.
Fitzgerald, Desmond, C.E., 225.
Flagging, 161.
Flanged pipe, standard dimensions of, T134.
Flies, carry typhoid 337.
Flood, West Va., 385.
Floor-beams strength of, T228.
Florida, N. Y., experiments, T135.
Flow
depth for maximum discharge, in conduits, T214, note.
over dams, 271.
in sewers, T214, T215.
rate of in filter-beds, 355.
to artesian wells, 323.
to open or driven wells, 329.
to and out of rocks, T193.
to and out of gravels, etc., T194.
Flues, long, effect on draft, 293.
heating surface of, T175.
measurements of, etc., T151, T152.
Flush tanks, cost of, T221.
importance of, 412.
Foaming, boiler waters, 346.
effect compounds, table compounds T196; see also boiler W, 345.
Food, pure, effect on life, 410.
Food & drink, adulteration of, 410.
Foot, cu., 32 equivalents of, T33.
decimal parts, equivalents in inches, T16. (lineal ft.)
square, equivalents of parts of in sq. in., T29.
Foot-pound, value, 242; equivalents in electric and heat units, T146.
Foreign
measures, length, T23.
monies, value & U. S. equivalents T44, T45.
sq. or land measure, T30.
weights, alphabetical, with U. S. value, T42.
weights, nations alphabetical with U. S. value, T
Foreman, pipe lines, T120 T139.
Forests, effect promiscous ber cutting; size reserv ground water, springs, w water power, 319, 320.
Foundations
dams, see dams.
quick sand, porous soil, 331, 379.
stand pipes, 261.
Franchise, traction, 235.
Franck's rule, 53.
Freezing, lead pipes, pumps to prevent, 314; ervoirs, 396; retaining w backing, 397, 399; pr tion ice removal, filter- 360; sewage, F-B, 447.
French, sq. or land mea T26-7.
French weights, 12-14.
Friction, coefficient of, for sonry, 391.
Frost, effect.
earth, 379; embankm 383; core wall, 383; dations, 261; roads, 1 F-B, 447.
Frustum cone, pyramid, 53
contents, 73.
Fuel & steam notes, 240-2
Fuel
evaporative power of, T148.
oil, 248; oil vs. coal, petroleum, 247; wood, saving heating feed T170; burned by chi T171; boilers, 283; pu plants, T180; small p 291.
best height, chimneys T187.
burned on grates, 296, duty pumping engines, 317.
Functions, trigometric, T

G

Gallons
discharge, pipe line T120-131.
water, cost at, various T154.
service pipes, dischar T142.
equivalents of, 26 27,
rainfall equivalents, T213.
reduction table, miner T160.
equivalents, million gal
Gas, chimneys, composi 292.
products combustio
Gas engines, 289.
Gasoline engines, 320.
Gates, hydrant br

ves.
see intakes.
boilers, 295.
se, see various
l filtration.
e effluent, 437.
d, 335-338.
ng point, etc.,
l pipe, 422, 423.
orse, 172; roads,
237, 240.
urvature. T106A
produce flow, in
pe lines, T120-
ified pipe lines,
nt of, T108.
ents, table costs,
e, life, etc.,
in, 327.
hold and deliver
.
es, pipe lines,
used by T192.
equired. 165.
, boilers, 296.
t of, T108.
hold water, T194.
in concrete, 432.
ow to find, etc.,
amt. of T194, p.
ed, road work,
19.
detailed data
179, 180.
approached, 378.
eration, effect on
ipe lines; auth-
ments, 415, 419-
cular solid, 73.
ces, 75.
d metal, T108,
of, road metal,
find, 185 (quick
.)
ith weights per
.. and various
T119.
iler waters, 346.
., C. E., 194.
quivalent costs
and transporta-
). and net ton,
and care in mix-
4.
to sub-soil, 380.
in mixing, 384.
walls, 383.
& *J. B.* Rider,

Grubbing, clearing for roads, 149.
Guard rails, for fences, 164.

H

Hamburg, cholera epidemic, 344.
"Hammer water," 375; author's experiments, 375-376; use of effect in hydraulic rams, 376, 275, 276.
Hard-pan, sand washed from for filter-beds, 354, 355.
Hard waters, 339, 345-6-7.
Head, pressure, in ft.
equivalent in lbs. sq. in., T141.
water, produce h. p., T156.
lost in c. i. pipe lines, T120-131.
lost in service pipes, T142.
lost in sewers, drains, culverts, T214-215.
water, for given h. p., T156.
weight c. i. pipes to resist, T137.
weight and thickness all sizes lead pipe to resist, T153.
Health, general, effect bad water, 433.
Heat
effect applied to steam, 280.
measures, equivalents, T145-146.
mechanical equivalent, 242.
amt. used heating air, 400.
units of, etc., 241; units in water, T173; units from fuel, 245.
vaporization, 280.
Heaters, feed water, 298.
Heating power, coals, T148.
Heating surface boilers, 295; amt. required, all types, T188; amt., of boiler tubes, T175.
Heating rooms & buildings, 400-6.
air, hot water, steam, exhaust steam, conducting and radiating power substances, coils, horse power boilers, etc., 400-6.
Hemp, in water pipe joints, amt. and cost, T139, T120-131.
High Bridge, N. J., WW., 334.
Highway embankments, 378.
Highways, see pavements, roads.
Horse, tractive power of, 172.
Horse power
chimneys, T171.
equivalents, T146.
steam engines, 302.
steam pumps, 317.
water motors, 256, T156.
water, to raise, T163, 311.
water, various heads, T156
water wheels, 259.

sts, per net, gross, lb. equivalents,

ies, T37.
ingular, T19.
11.
square or land, T43.
209; foreign, T23,

; U. S. and for-

; metric, T41;
T43.
and, 24, U. S.

T17, T18,
tration, 57.
arranged alpha-
k.

7.
0.71.
s, see pavements &

dpipes, thickness

al length 0.1 of,

er, 253, 254.
., rainfall on in
lits. T191.
269. 270.
, 24; reduction
0: discharge in,
, T161; pipe lines,

conds, in decimal
50.
ations, U. S. value
45.
carry germs. 337.
er, 255. 256.
r of, 172.
on. short methods,
25 x 25, 9.
barometer, T190,

oles made by. 382,

N

ilter, plan of, 349.
hannels, flow in,

es, tangents, co-
cosines, T56-100.
oss ton, lb. equiva-
s, per, T133.
easure sewage pur-
443.
indicator sewage
tion, 409.
e dept., hose, 371,

fire streams, T201.
discharging capac-
199.
lscharge of, T155.
mil. C.E., 232.
effluent, chemical
m. 437.

Numbers, consecutive, sq. of, 62, 68.
cube, cube root, sq. and sq. root of, from 0.1 to 1000, T46-46H.
Norwalk, Conn., typhoid fever at, 338.
Notes, sanitary, 407-454.

O

Oil, in boiler waters, 346.
as fuel, 247, 248.
Olefiant gas, combustion of, T147
Open wells, 327-3
Organic matter,
water, purificati
how to find, qua
O discharge
O decimal o
Overflows, crest, und, T162.
dams, 271, 272, 384.
floods over, 384, 385.
sewers, for storm water, 414.
Owen, James, C.E., 183.
Oxygen, effect at fires. 362.
combines, with organic matter, 434.
required, combustion, 244, 245.
Oysters, typhoid germs in, 435.

P

Paint, effect limestone on, 185.
Parabola, area of, 53.
Paraboloid, contents of, 74.
frustum of, contents of, 74.
Parallelogram, area of, 53.
Paving, rip-rap, 382.
stone, cobble, 161, 179.
Pavements and roads, 148-193.
classes of, are arranged alphabetically: asphalt to Telford, engineering, contracting, construction data, etc., 174-193.
cost to restore, T132.
specific gravity and weight of materials, T108.
how to find, 185.
for various amt. voids, T119.
tractive force, 172-174.
tractive resistance, 172-174.
Pavements, various.
asphalt, asphalt block, 174-176.
belgian block, 176, 177.
brick, 177, 178.
charcoal refuse, 179.
chert, 179.
cinders, 179.
clay shale, 179.
clay and sand mixed, 179.
cobblestone, 179.
gravel roads, 6 in., 8 in., 1 in., 179-182.

[illegible]

[illegible]

s, area of, 54: con-
: table, T55.
area, 54, table of
ule, 53.
ement, and mortar,
plastering, 432.
ivalent costs, net,
T133.
:s, see various
weights, etc., 10-
n, chemical, sew-
ibankments on pipe
, 391.
, 252, 396.
, 283: back, 283;
'176.
dams, walls, etc.,
nts in pounds,
fire streams, see
s.
ipe lines, see pipe
, 53; contents, 74.
ms of, 75.
see wedge.
formula, examples,
n of, 77; quick
o avoid use of, 76.
ibankments, 380,
6; settling of, 378.
iches, 379.
. 330.
ngines, see also
'180; 315-317.
370.
material by, 290,
required, T179.
370.
ter, 424.
t. Phila., 254.
re protection, 363-
ls, 289-291, 320,
ls, pumping grout,
T182.
181.
T169.
lischarge of, T178.
tes, tables, etc.,
ieral data, duty,
17.
oles, 289.
general data see
nes, 302-311.
see organic mat-
, *sewage dispos-*

Purification sewage, 433-454.
Pyramid, area, 52; contents, 72.
frustum, area, 53; contents 73.
Pyrometer, tests chimney gases, 293.

Q

Quantity, discharge, see pipes, sewers, etc. "amount" (amt.) is used in lieu of, in many cases.
Quick-sand, excavation, precautions, etc., 331; foundations, 261, 379; trenches, 424.

R

Rams, hydraulic, 275, 276, 376.
Rainfall
table equivalents, million gallons, 266; per sq. mile, T191; floods, 384, 385; equivalents, 1 in., T213.
Railing, bridges, 164.
Rails, middle ordinate of, T105A.
elev. of, on curves, 137, 138.
R. R. track, curves equivalent, grade, T106A.
R. R. embankments, 378.
Race ways, see overflows.
Radian, value of, 78.
Radius, circle, see circles.
Radius, hydraulic mean, 273.
Rafter, W. B. Rider table of, lengths main, hip and valley, T229, 459.
Rams, hydraulic, 275, 276, 376.
Receivers steam, 301, 302.
Red, sandstone, wells in, cap to hold, discharge water, etc., 325-327.
Refilling trenches, T120-131.
Remittent fever, 338.
Rensselaer Poly Inst., 194.
Rents hydrant, 373.
Repairs, pavements, T132.
Reservoir
bottoms, algae growths on, removal soil from, 341; excavation mud, 330; see also "brief water and supply notes," 318-347; dams, embankments, etc., F. & A. etc.
Retaining walls
for coal 399.
for earth, 397-399.
for water, 386-397.
Rider, John, use alum by, 361.
Rider, W. B.
cost roads under, 181.
Orange, N. J., water works, 184.
water works constructed by, 231.
dams constructed by, 384.
dams dangerous, monograph on, 386.

[redacted]

pipe, quality of,

pipe, 423.
in wet trench,

ngth of pipe, 424.
; tests of, 425;
, 425; color and
pe, 425; cement

rice list pipe, 426.
t length in car

ces, charge for,

price list, pipe,

data relative to,

larger sizes; also
r, T220.
construct sewers,
ges, with details,
aces, etc., under
pervision, T221.
rs, 431, 432.
nstruct, T220.
of, 415.
ewers, 432.
division, circle,

lopes, road beds,

65.
, well excavation,

ulling, etc., cost
work, T221.
hose, 369.
metical, etc., 5, 6.
res, contents of, 38.
ule, 53.
natural, tables,
also see curves,

verted for sewers,

e, steam engines,

m pumps, 316.
proper, 382.
nge, 436, 437.
, 339.
ry, effect on health,

ures, T31-34, U. S.

T41; foreign, T42.

ts in, see various

gular, contents, 73.
, see sewage.
k, Ct., poor pave-
176.
tings, W W, T138.
avity, see gravity.
ns, macadam roads,
est of, 148-170.
ls, pavements, ab-
see pavements.

Sphere, area, 54; contents of, 75.
hollow, contents of, 75.
segment, area, 54; contents, 75.
zone, area, 54; contents, 75.
Spheroid, see ellipsoid, 53, 73.
Sprinkling streets, 189.
Springs, 333-335.
under dams, 383.
Square, area, diagonal, etc., 55.
and circle, various equivalents, 59.
two consecutive numbers, 62, 68.
numbers, 0.1 to 1000, T46,-46H.
root, numbers, 0.1 to 1000, T46-46H.
land measure, 20-24; foreign, T30.
Square mile, equivalents, 20.
rain fall on, 266, T191, T213.
Steam, action in cylinder, 304.
amt. used by duplex pumps, T181.
condensation, cylinder, 307.
condensation, pipes, 301, 307.
energy in cu. ft. of, 294.
entrained water in, 300.
exhaust, in heating, 406.
jet, removing "anchor" ice, 364.
leaks, boilers, etc., 297.
mean pressure, in cylinder, T176.
mechanical force of, 281.
pressure, temperature of, T168.
quality of, 306.
ratio, expansion of, 306, 307.
saturated or dry, when, 299.
saturated, properties of, T172.
specific gravity of, 281.
superheating, 301.
temperature, change to gases, 362.
velocity of in pipes, 302.
weight of, 281.
Steam drum, 302.
Steam engines, 302-311, see engines.
Steam
Engine and pump notes, 278-288, and fuel notes, 240-248.
pipes, size of, 298.
pipes, heating, see heating.
pumps, 311-317; discharge pistons, T178; coal used, T179; coal to raise million gallons, T180; amt. steam used, duplex, T181; compound, table of, T182; triplex, table of, T183.
centrifugals, with engine, T185.
"savers," 241.
trap, 302.

Stacks, boiler, 291-293.
Standpipes, for WW, 260-265.
  for buildings, 369.
Steamers, fire, 369, 370.
Steel, medium, acid, soft, 163.
  for bridges, 162.
  melting point of, T198.
  plates, thickness, weight, etc., T227.
  pipes, on curves, 363; rusting of, 365.
Sterilization, sewage, 440.
Stone, weight of, etc., T108.
  broken, amt. in stone roads, T118.
  broken, weight, cu. ft., cu. yd., T119.
  paving, 161.
  soft, instance purchase of, 184.
Stored waters, 340, 341.
Storm water, amt. of, 413, 414.
Storm water, table of, T213.
Storm water, over flows, 384, 414.
Strainer, filter bed, not one 446.
  on suction pipes, 313.
Streams, large discharge of, 272.
  pollution of, 433.
  self purification, limited, 434.
  see also rivers.
Streets, see pavements.
  repairs after storm, 413.
  railways vs. pavement, 177.
  sprinkling, 189.
Sub-drains, cost of, T221.
  absence of, effect on sewer discharge, 411.
  for pavements, 151, 186.
Sub-grade, pavements, rolling, 150.
Sub-soil water, amt. of, 411.
Suggestions, steam pumps, 314.

Tangents, natu
  T58-100.
Tanks, thicknes
  on towers, 26
  round, content
  gallons and t
  etc.
  septic, 449-451
Tapping, size
  pipes, T152.
Tar joint, pipe
Tax, hydrant,
  street sprinkl
Teacupful, T37.
Telford roads,
Temperature, a
  air compressi
  at fires, 362,
  combustion, T
  colors denotin
  effect on fire
  measures of c
Thermometers,
  alents, etc., 2
  centigrade co
  alents, T144.
Threads, brass
  wrought iron
  T152.
Timber and pla
  164.
Tile, underdra
  ments, 152.
  salt glaze 42
  T218, T219;
Toise, Canada,
Ton-mile, 172.
Ton, equivalent
  ton and poun
Tools, etc., ros
Towers, tanks,
Towers, cooling
Tracks, electr
  roads, 192.

ches, earth, rock, etc.
ta earth held by vitrified
es, 423.
w to cover pipe, rock
nch, 423-4.
sewage disposal beds, 447.
cautions, wet trench, 424.
ver trench, cost, etc.,
20, T221.
pe of for brick and con-
te sewers, 432; sheet pil-
g, cost, etc., T221.
ers, 432.
ter pipe trench, amt.,
st, etc., all sizes, T120-131,
39.
ngle, area, rules for, 55.
ht angled, functions of,

lique angled, 80, 81.
les, formulae, etc., 80, 81.
onometry, plane, 78-81.
lex, pumps, T183.
ley, electric, double, 235.
weight, 10, 11.
erculation, pipe lines,
36.
ing, brass, threads, 249.
old water
ect on amt. of solids in
wage, 409.
water supply, 339.
hoid fever
rtality of, 335.
cillus of, lives in, how to
l, effects freezing, 335.
w Haven case in 1901,
5, 336.
rms in water supply; ef-
t sunlight, storage water
, 336.
riod incubation, 336, 337.
acing cases, prevention
read, 336, 337.
idemics of, how to check,
c., 337.
fect flies, mosquitoes, 337.
aminations water, often
lueless, 337.
uses, of, how to prevent,
38.
milk supply, 338.
orwalk, Ct., case, 338.
stored waters, 340.
oysters, 435.
ffect tide water sewage dis-
osal, 435.

U

der-drains, see sub-drains.
gula, circular, area and
ontents of, 72.
ward filtration, 358.
thor's, eight years experi-
ents with, 359-361.
thor's report on, Phila.,
., 357-359.
lvantages of, 359.
st of, *often less than*
wnward, 360.
removal prevented by,
, 360.
natural laws, in accord with,
358-361.
purification obtained, 361.
value sedimentation in con-
nection with; author's plant,
360.
Schuylkill river, 359.
use of in sewage purifica-
tion, 449.
Urine, amt. in sewage and an-
alysis, mixture with faeces,
T211.

V

Vacuum, partial, correspond-
ing temps. water condensers,
T190.
Valves, see also, gates.
check, for pumps, 313.
for fire protection, 368.
foot valves, suctions, 313.
valves, hydrants, 367.
relief, 368.
safety, size of, etc., 295.
slide, of engines; stroke, lap,
how to set, 304, 305.
suction, 313.
rubber, brass, etc., when to
use, 314.
water works, 367, 368.
importance of brass stems,
nuts, etc., 368.
importance of all in system
turning in same direction,
368.
Vapor, saturated, 280.
Vaporization, heat of, 280.
Vegetable growths, in water,
343-4.
at Bethel, Ct., 351-353.
at Nantucket, analysis show-
ing 99.33 per cent. removed,
348.
effect on decreased stream
polution, 434.
in artesian wells, 321.
in reservoirs, effect depth,
clean bottom, sunlight, 341.
in sea water, 435.
"purging" of, stored waters,
341.
Velocity
acceleration of, effect, on dis-
charge sewers, 415, 419-422.
in pipe lines, see pipe lines,
discharge tables.
Ventilation
benefits of, 410.
buildings, air required, T205.
sewers, how provided for in
calculations discharge, 412.
Vibration, foundations, 261.
Vitrified pipe, lines, etc., cost,
material, T216, T218, T219.
cost to construct, T220,
T221.
discharge, sewers, T214,
T215.
material of, strength, tests,
construction data, etc., 422-
430.
use in irrigation, 443.

products co
various soli

Washing, san
Watt, electri
Walls, etc.,
pressure.
pressure or
centre line
n vertical
moments.
onry, 388
vertical re
ess of, 3
ressure o
ams, vari
orizontal.
mum com
390
ward
line lines
ams pre
paven
oefficient
walls, a
as for re
width, w
side alw
amples
urved
compar
thickne
ent ne
394 3
Intakes
395-397

...ious rates, T154.
...gate of, 253.
... factors of, T174.
...faces, 318.
...tion, amt. req.
... absorbed, etc.,
...tions, equivalent
... equivalents in
...n, T173.
... one, amt. to
...er various heads.
..., req. to elevate.
...amt. req., 320.
... amt. in, 438.
... amt. used by,
... used by, 256.
...linary, discharge
...c., 371-374.
...harge of, T155.
... lbs. equivalents
... inches water.
... in lbs., ounces,
... walls, etc., 386-
... lines, discharge
...n, 48 to 4 inch,
...d, 194.
...ne, T140.
...s, T142.
...s, T214, T215.
...use T120-131, de-
...m 10 to 15 per
...vets.
... sq. mile, equiva-
... ft. gals., etc.;
...our, equivalents
...eas, T213.
...arge of, T164-5.
... held by, T193.
... amt. held by,
...s, see above.
... req. for, 281.
...s, discharge of,
...ls, steam, T185.
... T182.
...85.
... T178.
...183.
...ngines, T179, 315.
... T166, T167.
... changed to
... and correspond-
..., T190.
... required to fill,
...lso voids.
...ls, amt. req. 259.
...uction tables.
... *T108*, T119, (cu.
... water, T119.
...ft., in, gals. T8.

cu. yd. to 19 other units, T32.
cu. ft. to 32 other units, T33.
cu. in. to 28 other units, T34.
U. S. gal., etc., to lbs., T36.
for others, see various tables weights, measures, etc.
wrought iron pipes, amt. held per ft., T151.

"Water hammer."
effect on lead pipes, 252.
benefit relief valves, 368.
text relative to, author's experiments, etc., 375, 376

Water meters, 253, 254.

Water motors, 255-256.

Water pumping, see various pumps.
cost at Phila., 254.

Water purification, 339-361.

Water-sheds
amt. now furnished by, 253.
effect forests, evaporation, etc., 318, 319.
New England, discharge of, 384.
quick method to find area, 377.
see also, "drainage cones" under well supplies.

Water-wheels, 258-260.

Water-works, from a fireman's or insurance Co. standpoint, 362-374.

Water-works pipe lines, 194-240.

Water and supply notes, 318-362.

Water, standpipes, 260-65.

Water tamping, 220.

Water tanks on towers, 263-265.

Water towers, (hose), 369.

Wave action on embankments, 382.

Wedges, all kinds, cuts of, contents of, short methods to find, 75, 76.
frustum of, (prismoid), 77.

Weight, atomic, carbon, hydrogen, etc., T147.
apothecaries, 11.
avoirdupois, tables, equivalents, etc., of, 11, 12.
commercial, 11, 12.
French or metric, 12-14.
foreign, with U. S. equivalents,
weights, alphabetically, T42.
nations, alphabetically, T43.
Troy weight, 10.
for other weights, see article in question.

Wells
artesian, 321, 322.
cost to drill, 327.
drainage cone, etc., 323, 324.
in granite rock, 327.
in red-sandstone and trap.

vestigation, etc.,

... into, 323.
driven and open wells, 327-333.
Well-curb, 331.
Well excavation, 330.
Well waters, 342.
Wells, White Plains, N. Y., 327.
Well-hot, 308.
Wells, salt water in, 329.
Weirs, 265-270.
discharge in.
California miners' inches, T161.
cubic feet minute, T159.
triangular notch weir, 265.
see also, for dams, 271, 272, 384, 385.
Wind
effect, stored water, 341.
heating buildings, etc., 402.
pressure, of, 260, 276.
on standpipes, etc., 260.
on towers and tanks, 263,
Wind-mills, 264, 276, 277.
giving capacity of pumping wind mills, construction and other data.
Wood, dry, 247.
comparative value as ... T149.
weight of various kinds, ... chord, 247.
Wooden beams strength, ... T228.
Wooden pipes, 365.
Work performed, day's wo...
in water pipe laying, T139
Worcester, Mass., sewage cl... ification at, 436, 437.
Wrought iron, melting poi... of, T198.
plates, weight of, 227.

Y

Yard
lineal, equivalents, etc., ...
cubic, 24.
19 equivalents of, T32.
square, equivalents of, T...
Yellow fever, 338.

Z

Zone, circle, area, cut of, ...
sphere, area of, 54.

ERRATA.

…g of the errors below given are due to type "pulling out" …printing. All will not therefore be found in every copy of …ok.

5, line 15, read, 4 is to 6 so is 8 to 12.
6, " 30, " quantity for quality.
7, " 5, " " " "
11, " 12, erase first s in avoirduposis.
14, Table No. 11, next to last line, read gross for cross.
15, line 13, * refers to paragraph next above Table …

26, in 2nd line under Table No. 36, read 1.10365 for 1.0365.
38, in 6th line under "Use of Cube Root," replace — by a ,.
48, in 2nd line of heading to Table No. 47, read, Base=10.
49, 3rd line under table, should end with figure 1 and not |.
53, in 15th line erase last "r" in frustrum.
64, in last line erase "a" before equivalent.
75, in 4th line relative to "Volume or Contents of Sphere" … one-sixth for ⅙.

77, in 6th line from bottom, add "n" in embakments be… a and k.

80, in 4th line under Fig. 20, add = after cot a and also after …

80, in next line add = after C at the beginning of the line.
94, in top side head, first line, add 1 after radius =.
135, in last line for — read =.
137, in 2nd line for table read length.
138, 12th line from bottom should end with =, instead of —.
139, in 1st line of body of Table No. 106, for foot read feet.
148, in 11th line, for page 168 read page 171.
189, Under "Street Sprinkling," 3rd line for prop- read …er.

190, * after the word "totals" for 4" and 6" road, refer …e last foot note on the page.

191, in 5th line from bottom, for they, read there.
192, beginning at "years" in 9th line from bottom read, …ith with proper repairs there is no reason to limit its … etc.

220, Erase 7th line from bottom, beginning with "By Table …57."

230, Weight of 6" × 4" Cross and Tee should change places.
237, in 20th line from bottom, for 15" read 16".
243, in heading to first column of Table No. 146, for B. T. T. … B. T. U.

254, in 17th line for chargable, read chargeable.
255, in 5th line from bottom for Table No. 155, read Table …156.

256, in 8th line for, of 300, read for 300.
261, in 4th line from bottom, for concrete, read granite.
266, in last line, for fell, read fall,
272, 5th line under table, take out one "r" in currrent.
276, in 1st line under table, seperate the words "price" and …es.

…e 281, in 3rd line from bottom, for 27,222, read 27,222; for 13,817 … 13,817.
307, in 18th line from bottom, for page 300, read page 301.
348, Table should be No. 197, and not No. 199.
373, in 8th line from bottom for mean, read means.
388, in 4th line under "Masonry" for, of up-stream, read to …stream.

…ge 388, erase the 13th line and substitute the following: the …ection of the slope and a vertical line .... (h)
…ge 390, in 5th line under "Upward Pressure" for 0.03125 read, …125.

…ge 421, for Q, read Q_1.
424, in last line for okam, read okum.
430, table number should be 221 and not 201.
448, *in 8th line from bottom, for involved read involving.*

…f other errors are found, the author would greatly appreciate …g informed.

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INDEX.

		PAGE
A	Acton, John,	42
	American Pipe M'f'g. Co,	24
	American Well Works,	23
B	Bacon, Earl C.,	31
	Berger, C. L. & Sons,	34
	Berquist, A. Samuel, C. E.,	42
	Blackmer & Post,	8
	Blickensderfer M'f'g Co.,	35
	Bookkeeper Publishing Co.,	33
	Bouborn Copper and Brass Works,	9
	Buckeye Engine Co.,	37
	Buff & Buff,	36
C	Caldwell, W. E. Co.,	27
	Carpenter Brothers,	32
	Coffin Valve Co.,	19
	Conrad, W. R.,	28
	Coryell Construction Co.,	42
	Cutler M'f'g Co.,	3
D	Davidson, M. T.,	18
	Deming Co., The,	16
	Dixon Crucible Co., Joseph	4
	Downie Pump Co.,	25
E	*Etheridge, H*	29

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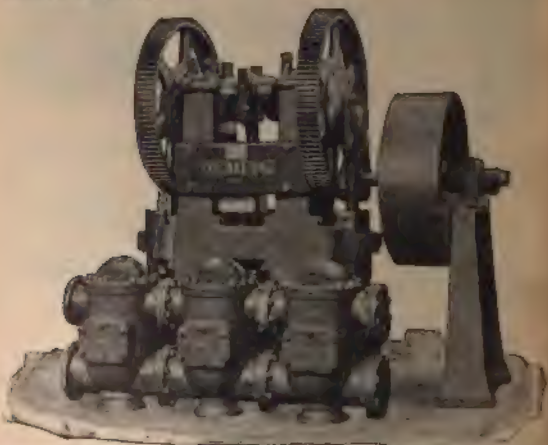

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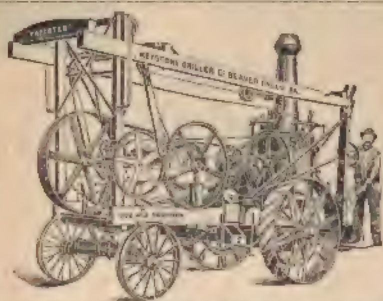
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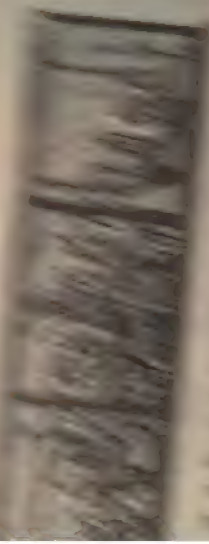

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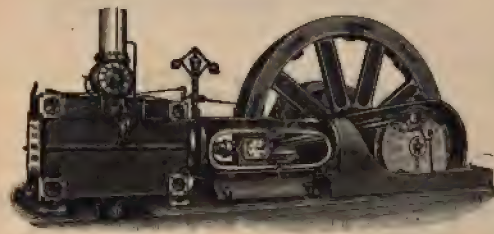

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